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Stock Assessment of Georges Bank (5Zhjmn) Yellowtail Flounder for 2004

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ABSTRACT

The combined Canada/USA yellowtail flounder (*Limanda ferruginea*) catch increased from 1995 to 2001 and in 2003 was 6,807 t, more than the 6,097 t caught in 2002 due to a large increase in discard estimates from the Canadian offshore scallop fishery, but below the catches in 2000 and 2001. Biomass has been generally increasing since the mid 1990s and recent year classes appear to have increased since the mid 1980s and are comparable to those in the 1970s. Fishing mortality rates were high in the past, but recently have been reduced. The population age structure displays a recent expansion, however, there are fewer fish in the oldest age classes in both the catch and surveys than would be expected given the previous perception of recent low exploitation. The increased uncertainty in current stock status, more severe retrospective pattern, and the divergence in model results as well as the failure to explain the absence of older fish in the catch gives no confidence in projection results. Considering the trends in survey abundance and recruitment, status quo catch or lower may be an appropriate management approach until these issues are resolved.

RÉSUMÉ

Les prises combinées de limande à queue jaune du Canada et des États-Unis (*Limanda ferruginea*) ont augmenté de 1995 à 2001 et en 2003 elles se chiffraient à 6 807 t. Ce résultat était supérieur aux 6 097 t capturées en 2002, en raison d'une forte hausse des estimations de rejets dans la pêche hauturière du pétoncle par le Canada, mais inférieur aux prises de 2000 et 2001. La biomasse a été généralement en hausse depuis le milieu des années 1990 et les classes d'âge récentes semblent avoir augmenté depuis le milieu des années 1980, pour se comparer à celles des années 1970. Les taux de mortalité par pêche étaient hauts par le passé, mais ils ont diminué récemment. La structure d'âges de la population dénote dernièrement une expansion; toutefois, tant dans les prises que dans les relevés, il y a moins de poissons des classes d'âges les plus anciennes qu'on l'attendrait compte tenu du fait que l'exploitation récente a été perçue comme étant faible. Étant donné l'incertitude accrue au sujet de l'état actuel du stock, une tendance rétrospective plus prononcée et l'écart dans les résultats du modèle ainsi que l'incapacité d'expliquer l'absence de vieux poissons dans les prises, les résultats des projections n'inspirent pas confiance. Si on considère les tendances de l'abondance et du recrutement dans les relevés, le statu quo ou une baisse dans les prises pourrait être une bonne stratégie de gestion tant que ces problèmes ne sont pas résolus.

INTRODUCTION

Georges Bank yellowtail flounder *(Limanda ferruginea)* are a transboundary resource in Canadian and US jurisdictions. This paper updates the last stock assessment of yellowtail flounder on Georges Bank, completed by Canada and the USA (Stone and Legault 2003). Similar methods are used in the current assessment, with updated catch information and indices of abundance from both countries. Last year, the outlook was more uncertain than in past years due to an increase in the retrospective pattern seen in the age-based analytical assessment and divergence between the age-based assessment and production model results. The increased uncertainty in current stock status and the divergence in model results as well as the failure to explain the absence of older fish in the catch gave very little confidence in projection results, therefore status quo catch was recommended as an appropriate management approach until these issues are resolved.

Yellowtail flounder range from southern Labrador to Chesapeake Bay and are typically caught at depths between 37 and 73 m. A major concentration occurs on Georges Bank from the northeast peak to the east of the Great South Channel. Yellowtail flounder have previously been described as relatively sedentary, although a growing body of evidence counters this classification with limited seasonal movements reported (Royce *et al.* 1959; Lux 1963; Stone and Nelson 2003; C. Glass pers. comm.) as well as transboundary movements to the east and west across the international boundary (Stone and Nelson 2003; S. Cadrin pers. comm.). On Georges Bank, spawning occurs during late spring and summer, peaking in May. Eggs are deposited on or near the bottom and after fertilization float to the surface where they drift during development. Larvae are pelagic for a month or more, then develop demersal form and settle to benthic habitats. Based on the distribution of both ichthyoplankton and mature adults, it appears that spawning occurs on both sides of the international boundary. Growth is sexually dimorphic, with females growing at a faster rate than males (Lux and Nichy 1969; Moseley 1986; Cadrin 2003). Yellowtail flounder appear to have variable maturity schedules, with age two females considered 40% mature during periods of high stock biomass to 90% mature during periods of low stock biomass.

Tagging observations, larval distribution, life history traits, and geographic patterns of landings and survey data indicate that Georges Bank yellowtail flounder comprise a relatively discrete stock, separate from those occurring on the western Scotian Shelf, off Cape Cod and southern New England (Lux 1963; Neilson et al. 1986; Cadrin 2003; Stone and Nelson 2003). The management unit recognized by Canada and the USA for the transboundary Georges Bank stock includes the entire bank east of the Great South Channel to the Northeast Peak, encompassing Canadian fisheries statistical areas 5Zj, 5Zm, 5Zn and 5Zh (Fig. 1a) and U.S. statistical reporting areas 522, 525, 551, 552, 561 and 562 (Fig. 1b). Both Canada and the USA employ the same management unit. The quota sharing agreement between the two countries requires that catches from all sources be counted against the national allocations, regardless of whether the catch was landed or discarded.

The Fisheries

Exploitation of the Georges Bank stock (NAFO Statistical Areas 5Zhjmn) began in the mid-1930's by the US trawler fleet. Landings (including discards) increased from 300 t in 1935 to 7,300 t in 1949, then decreased in the early 1950s to 1,600 t in 1956, and increased again in the late 1950s (Fig. 2). The highest annual catches occurred during 1963-1976 (average: 16,300 t) and included modest catches by foreign fleets (Table 1). No foreign catches of yellowtail have occurred since 1975. In 1985, the stock became a transboundary resource in Canadian and US jurisdictions. Catches averaged around 3,000 t between 1985 and 1994, then dropped to a record low of 817 t in 1995 when fishing effort was drastically reduced in order to allow the stock to rebuild. The USA fishery in the management area has been constrained by spatial expansion of Closed Area II in 1994 (Fig. 1b) and by extension to year-round closure in 1995, as well as net regulations and limits on days fished. A directed Canadian fishery began in 1993, pursued mainly by small otter trawlers (< 20 m). Landings by both nations have steadily increased (with increasing quotas) from a record low of 817 t in 1995, when the stock was considered to be in a collapsed state, to 7,926 t in 2001. In 2003, combined landings for both nations (including discards for the US and Canadian fisheries) were 6,807 t.

USA

The principle fishing gear used in the US fishery to catch yellowtail flounder is the otter trawl, but scallop dredges and sink gillnets contribute some landings. In recent years, otter trawls caught greater than 95% of total landings from the Georges Bank stock, dredges caught 2-5% of annual totals, and gillnet landings were less than 0.1%. US trawlers that land yellowtail flounder generally target multiple species on the southwest part of the Bank, and on the northern edge along the western and southern boundaries of Closed Area II. Current levels of recreational fishing are negligible and there have been no foreign catches since 1995.

US landings were prorated to stock area using logbook data as described in Cadrin et al. (1998). Since 1995, the proportion of total yellowtail landings accounted for in logbooks had exceeded 90% (e.g., in 1999, 97% of total landings were accounted for). However, in 2000 the proportion dropped to 85% (primarily resulting from low proportions in the fourth quarter of the year), then increased to 88% in 2001 and 92% in 2002 and 2003. This reduced proportion adds uncertainty to the estimate of yellowtail landings by stock area, particularly for 2000 and 2001. However, examination of patterns of landings reported in the dealer database and those in the logbook records show similar trends in terms of time of year, gear, and port. Thus, there is no indication of a systematic bias in these allocations. Total yellowtail landings (excluding discards) for the 2003 directed fishery were 3,343 t, an increase of 24% from 2002, but below the landings in 2000 and 2001 (Table 1; Fig. 2).

Discarding of small yellowtail in the US fishery has been a source of mortality due to intense fishing pressure priot to 1995, discrepancies between minimum size limits and gear selectivity, and trip limits for the scallop dredge fishery. In 2003, 90% of yellowtail flounder discards originated from the offshore scallop fishery (244 t), while the

remainder came from bottom trawl catches (27 t). Due to the lack of reported yellowtail landings in the scallop dredge fishery in 2003, the traditional kept to discard ratio approach to estimating discards could not be applied. Instead, the ratio of discarded yellowtail flounder to kept scallops was computed from observer trips and applied to the scallop landings. Since there were only two observer trips on scallop dredges fishing on Georges Bank in 2003, the four observer trips from 2002 were also used to calculate the discard to kept ratio. Applying this ratio to scallop catches in 2002 produced a dredge discard estimate of 177.8 t, which is much lower than the estimate of 445.7 t using the traditional discard to kept approach for that year. Applying the discard yellowtail to kept scallop ratio to scallop landings in 2003 resulted in a dredge discard estimate of 244.0 t. Total US catches in 2003, including discards, were 3,614 t.

Canada

Canadian fishermen began directing for yellowtail flounder in 1993. Prior to 1993, Canadian landings were small, typically less than 100 t (Table 1, Fig. 2). Landings of 2,139 t of yellowtail occurred in 1994, when the fishery was unrestricted. After a TAC of 400 t was established, yellowtail landings dropped to 472 t in 1995. Since then both quotas and landings have increased steadily and in 2001 were 2,913 t. In 2003, landings were 2,107 t (against a quota of 2,266 t), and were down 20% from 2002 (Table 1). The majority of Canadian landings of yellowtail flounder are made by otter trawl, from vessels less than 20 m, tonnage classes 1-3. The Canadian fishery generally occurs from June to December, with 64% of landings in 2003 reported in the third quarter. Unlike other years, in 2003a larger component of landings occurred in June (374.1 t) since license conditions were available earlier than other years.

Flatfish landed as "unspecified" in the Canadian fishery have been significant in previous years, and generally consist of yellowtail on Georges Bank. Neilson et al. (1997) revised the landings data for earlier years of the fishery (1993-1995) to account for catches of unspecified flounder species. The unspecified flounder problem has become less significant recently, due to improved reporting practices. For the 2003 fishery, the proportion of yellowtail catch in unspecified flounder landings was estimated by applying the monthly proportions of known yellowtail landings in 5Zm and 5Zj (based on the ratio of known yellowtail catch to known yellowtail + other flounder species catch) to unspecified flounder landings from matching area/month strata. Total unspecified flounder landings in 2003 estimated to be yellowtail, were 2.2 t and 16.1 t for 5Zj and 5Zm, respectively, and are included as part of the Canadian landings (Table 1).

In 2001, summer flounder (*Paralichthys dentatus*) was captured in the Canadian fishery (mostly August through October), and was reported as "unspecified" since it is uncommon in Canadian waters. This amount (estimated to be 1%) represented 26 t of the total yellowtail catch and was subtracted from the total landings (including unspecified estimated to be yellowtail) to give the revised total of 2,913 t for 2001. In 2003, summer flounder catches of 11.4 t were identified and reported as a separate species in the commercial landings data, so no adjustments to the total yellowtail landings were required.

Canadian yellowtail directed fishing activity is concentrated in the southern half of the Canadian fishing zone, in the portion of 5Zm referred to as the "Yellowtail Hole". Overall, the fishery distribution in 2003 was comparable to that observed over the previous five years, but with some catches occurring further north along the edge of the international boundary, similar to 2002 (Fig. 3).

In past years, there have been landings of yellowtail flounder in the Canadian offshore scallop fishery on Georges Bank. Reported landings of yellowtail flounder from 1968 to 1995 (adjusted for landings of unspecified flounder) were low (mean =14 t) and ranged from 0-55 t (Table 1; Figs. 2 and 4). Prior to 1968 no reliable groundfish landings information is available for the offshore scallop fishery. Management measures established in 1996 prohibit the landing of yellowtail flounder by the offshore scallop fleet and no records of discarded quantities have been available from 1996 to the present. Recently, a monitoring program was conducted by the Canadian offshore scallop industry in 2001-2002 to examine yellowtail flounder bycatch (along with cod, haddock and monkfish) (Kenchington 2002). Twelve observer deployments on offshore scallop vessels were conducted between May 2001 and April 2002 with most trips occurring in 5Zj. During each observed trip, approximately 80% of the scallop tows were monitored for yellowtail bycatch, so yellowtail catches were prorated to represent the total bycatch per trip. Since there is a spatial component to the groundfish movements on the bank, yellowtail bycatch ratios (weighted averages) were calculated as a percentage of total scallop effort (hours fished provided by Ginette Robert, Invertebrate Fisheries Division) for observed trips grouped by NAFO area (5Zj, 5Zm). These ratios were then multiplied by the 2001-2003 offshore scallop effort (hours fished) by NAFO area for Offshore Scallop Management area "A" and "B", and summed to provide annual estimates of total yellowtail bycatch. In addition, eight observed trips from 1994-1998 also had information on yellowtail flounder bycatch and were used to calculate bycatch ratios for each area (i.e.5Zj and 5Zm). The ratios were prorated by scallop effort (hours fished) for 1996-2000 to provide annual estimates of yellowtail flounder bycatch. Although the overlap between the period of observer coverage (1994-1998) and the fishery (1996-2000) is not the same, no other sources of data were available for this period. The yellowtail flounder discard estimates for 1996-2003 ranged from 116-1086 t (mean=415 t), with the highest estimates occurring during the past three years (i.e. 814 t, 457 t and 1086 t for 2001, 2002 and 2003, respectively; Table 1; Fig. 4).

Noteworthy is that our recent bycatch estimate of 814 t for 2001 is considerably higher than the estimate of Kenchington (2002) for the same year (i.e. 280-390 t). There are several reasons for the difference between these two estimates, the main ones being that those of Kenchington were based only on the 2001 observed trips from May through December, and did not include the observed trips from January to April 2002, when the yellowtail bycatch was quite high. Also, Kenchington used a different measure of effort in his calculations (i.e. scallop trips and landings) for expanding from observed data to fleet-wide bycatches, which was limited to Offshore Scallop Management area "A". Our calculations were based on hours fished for observed trips expanded to hours fished for the entire fleet, and included effort for Offshore Scallop Management areas "A" and "B". Also of interest is that the average total trip effort in hours for the observed trips was substantially less than the average for the unobserved trips. The May to December trips were about 30% longer while the January to April trips

were almost double. This difference in trip length results in the observed bycatch rate being applied to a substantially greater number of hours when our method is applied, resulting in higher estimates of total bycatch.

When Canadian yellowtail flounder catches were revised to include the discard estimates from the offshore scallop fishery, the annual quota, which was first implemented in 1994, was exceeded in all years (except 2000) by an average of 303 t (range=100 t - 880 t). For 2003, the total Canadian catch including estimated discards was 3,193 t against a TAC of 2,266 t.

Length and Age Composition

In 2003, the Canadian fishery was well sampled for lengths by sex, with 5,943 measurements available from 27 port samples (Table 2). Sea samples from 9 commercial trips provided an additional 5,965 length measurements by sex. Examination of the size composition from at-sea samples and port samples collected during the same quarter showed that the size composition by sex was quite similar and that there was a distinct seasonal pattern with more females present in the catch during the 2nd quarter, shifting to male predominance in the 3rd and 4th quarters (Fig. 5). This could indicate either movement of males into the Yellowtail Hole during the 3rd and 4th quarters, or removal of a greater proportion of females by the commercial fishery early on in the season. Given the similarity between the two sources of size information (i.e. port vs observer), length data from the 9 observed trips were combined with the DFO/Industry port-sampling program to characterize the size composition of the Canadian fishery.

Canadian at-sea length frequency information for 2003 also indicated that culling on the basis of length was not a major concern in the 2003 fishery (Fig. 5). While the Canadian fishery currently has a minimum fish size limit of 30 cm total length, this size regulation is seldom enforced. Since 1993, the percentage of undersized fish (i.e. < 30 cm by number) has rarely exceeded 4% of the total reported catch and has been below 1% for the past three years (Fig. 6). In 2003, only 0.9% of fish in the Canadian commercial catches were less than 30 cm.

The average size of yellowtail flounder in the Canadian fishery increased between 1994 and 2002 from 33 to 35 cm total length for males and from 35 to 41 cm for females (Fig 7). While the average size of males in the fishery did not change in 2003 (35 cm), the mean size of females declined to 38 cm. The proportion of males in the catch increased from 25% in 1999 to 65% in 2002, but declined to 50% in 2003.

The number of US port samples increased in 2003, with 4,877 length measurements available from 46 samples (Table 2). This compares with 2,533 measurements from 26 samples in 2002. At-sea sampling also increased in 2003 and provided an additional 4,196 length measurements, which were combined with the port samples to characterize the size composition of the US catch.

The US landings are classified by market category (large, small, and unclassified) and this categorization is used to determine the size and age distributions.

Both the amount and the proportion of yellowtail landed in the large market category have increased since 1995 (Fig 8). Examination of the size distributions for the two market categories shows some overlap in the 35-40 cm range, but overall discrimination between the groups (Fig. 9). The proportion of the landings within the large market category that are 45 cm and larger has increased monotonically since 2000; 5%, 8%, 12%, 22% for years 2000 through 2004, respectively.

A comparison of the catch at size by nation indicated that the US fishery generally had a larger size composition than the Canadian landings (Fig.10). Most of the Canadian landings occurred in the 30-45 cm size range with a mean size of 36 cm TL, while US catches (landings plus discards) were represented mainly by fish in the 33-49 cm range, with a mean of 39 cm TL. Most of the US fishery catches (63%) occurred during the first half of the year, while most of the Canadian catches (83%)occurred during the second half (Table 2). Seasonal and geographic differences between Canadian and US fisheries may account for some of the difference in size composition observed in 2003. Although net selectivity is not suspected as a major source of the difference due to the similarity between the cod end mesh sizes used by US and Canadian fishers (i.e. 165 mm square or diamond for US fishery vs 155 mm square in CDN fishery), the slightly smaller Canadian cod end mesh size has the potential to retain more small fish as indicated in Fig. 10. The US fishery catch at size includes discards from bottom trawl and offshore scallop fisheries. Yellowtail flounder discards from the Canadian offshore scallop fishery are not included in the Canadian fishery CAS because observer sampling for length information was not proportional to the catch, but the catches are expected to have a similar size composition as the commercial fishery.

During a recent yellowtail flounder aging workshop, it was concluded that otolith thin sections are the preferred structure to use for age determinations in this species on Grand Banks (Walsh and Burnett 2001). However, precise age determination of Georges Bank yellowtail flounder using otolith thin sections is hampered by the presence of weak, diffuse or split opaque zones and strong checks, which can make interpretation of annulii subjective and difficult (Stone and Perley, 2002). Age determination results from recent inter-laboratory exchanges (i.e. DFO/NMFS and DFO/CEFAS) of scales and otoliths collected during DFO bottom trawl surveys have so far been disappointing with < 55% agreement on these structures between expert age readers. In 2003, scale samples were collected from the Canadian fishery for aging by the NMFS age reader. A total of 137 male and 192 female ages were used to produce separate-sex age-length keys which were applied to Canadian length samples to construct the catch at age (CAA) by sex for the 2003 commercial fishery. A comparison of the 2003 Canadian commercial fishery CAA using the traditional approach based on ALK's from the US commercial fishery (2^{nd} half) plus NMFS fall survey ages (n=585) and the new approach using Canadian fishery scale samples aged by NMFS (n=329) indicated that both methods produce similar results (Fig. 11). This is not a test for ageing errors, but rather an indication that borrowing the US commercial ALKs did not have a large impact on the Canadian CAA.

For the US fishery, sample length frequencies were expanded to total landings at size using the ratio of landings to sample weight (predicted from length-weight

relationships by season; Lux 1969), and apportioned to age using pooled-sex age-length keys in half year groups.

In 2003, age 2 and 3 males and age 2-4 females made up most of the Canadian catch, with more age 3's (2000 year class) present overall for both sexes compared with 2002 (Fig. 12). The Canadian CAA also indicates a broader age distribution for females (ages 1-7) compared to males (ages 1-5). Since 1994, the mean length at age for male yellowtail flounder in the CAA has been relatively consistent at ages 2 and 3, but has been variable with a declining trend evident in recent years for ages 4 and 5, although small sample sizes make conclusions regarding these older ages difficult (Fig. 13). For female yellowtail, the mean length has been relatively consistent across ages with an increasing trend from 1997 through 2002, however, a slight decline is evident in the most recent year. This analysis suggests that mean length at age has been less variable for females compared to males and indicates relatively good consistency in age determination.

Although calculations of the size and age distributions for US landings are not traditionally done using information on sex, for the purposes of comparison it was done for the 2003 landings. The resulting landings at age distributions when sexes were treated separately differed by less than 5% at every age from the traditional sexes combined approach (Fig 14). Average size for males was 36 cm and for females was 40 cm, slightly larger than the average sizes in the Canadian landings for both sexes. The overall sex ratio for US landings in 2003 was 12% males and 88% females. This high proportion of females was corroborated with data collected during an ongoing tagging study (kindly provided by S. Cadrin, NMFS). The tagging data was collected from a single boat during one week in July 2003 from three separate locations on Georges Bank, areas 522, 525, and 562. The fish were collected by a trawler using short tows. The fish tagged in area 562 were caught in approximately the center of Closed Area II, while the fish caught in areas 522 and 525 were caught in areas open to fishing. The sex ratios of the fish caught for tagging varied by area, but was always predominantly female, with almost only females caught in CAII (Table 3). The size distributions of the female yellowtail caught during this tagging study also varied by area, with larger females found in CAII than in the open areas (Fig 15).

In 2003, the US catch at age (landings plus discards) was dominated by ages 3 and 4 (2000 and 1999 year classes, respectively), which represented 38% and 27% of the catch. Compared with the 2002 US fishery age composition, there were fewer at age 2 but more at ages 4+ in 2003 (Fig. 12). The Canadian landings in 2003 were dominated by ages 2 (2001 year class) and 3 (2000 year class), which represented 38% and 42% of the catch, respectively, with fewer older fish in the catch compared to the US fishery (Fig. 12). The proportion of landings in the oldest ages (6 and greater) has increased dramatically in the US fishery in recent years and has increased in the Canadian fishery, although the most recent years have declined from the peak in 2001 (Fig 16). Overall, the 2003 catch age composition was represented by the 2001 (age 2) and 2000 (age 3) and 1999 (age 4) year classes, with age 3 dominant (Fig. 17, Table 4). Since the mid 1990s, ages 2-4 have represented most of the exploited population, with very low catches of age 1 fish since the implementation of larger mesh in the cod end of commercial trawl gear.

Mean weight at age was calculated from Canadian landings (separate sex) and USA (combined sex including discards) fishery CAA data (Table 5, Fig. 18). The commercial fishery mean weight at age data was revised in the 2000 assessment to include calculated weights for age 1 fish rather than the assigned value of 0.01. A slight increase in WAA for ages 2-4 has occurred since 2001, but a more pronounced increase is apparent for ages 5 and 6+ from 1997 to present. However, current WAA values are within the range of past WAA calculations since 1973 and showed little change from 2002 to 2003.

ABUNDANCE INDICES

Commercial Fishery Catch Rates

A standardized catch rate series was developed for the Canadian fishery using a multiplicative model that was solved using standard linear regression techniques after *ln* transformation of nominal CPUE (t/hr) data (Gavaris 1980, 1988a). For this analysis, only trips in 5Zm with ≥ 2.0 t of yellowtail landed were included (n=1400), and were assumed to represent directed fishing activity for yellowtail flounder. Due to changes in the structure of the commercial landings database, the 2003 fishery effort data was only available up to the end of September, however, catches from these trips represented 74% of overall landings. A model with main effects of year (1993-2003), month (June-December) and tonnage class (1-3) was used to standardize the Canadian CPUE series:

$$ln(CPUE_{ijk}) = \mu + Year_i + Month_j + Tonnage\ Class_k + e_{ijk}$$

Analysis of variance results (Table 5) indicate that the overall regression and individual main effects were significant ($P < 0.05$) and that the model explained 61% (multiple r^2) of the variability in the data. No trends were apparent in the pattern of residuals (Table 6, bottom) and the standardized series tracked the nominal series (weighted mean) quite well (Fig. 19, upper panel).

Standardized catch rates decreased between 1993 and 1994 but increased by a factor of two between 1994 and 1995, with a further increase in 1996. Catch rates were stable from 1996 to 1998 then increased considerably in 1999 when some of the fleet switched to more efficient flounder gear. In 2000, catch rates dropped sharply, with a continued decline in 2001 to the second lowest level in the series, due to a greater than five-fold increase in effort from 1999 to 2001, and have remained at low levels through 2002 and 2003. In comparison with the DFO spring survey biomass index for stratum 5Z2 (Canadian portion of the bank <90 m), the CPUE series tracks the index up to 1999, but falls off rapidly thereafter (Fig. 19, lower panel). The Spearman rank correlation coefficient for these two series was not significant (r_s=0.484; P=0.236; n=11), suggesting that catch rates within the Yellowtail Hole have declined more rapidly in recent years than the Canadian portion of the bank (< 90 m) as a whole.

At the March 2001 industry consultation, it was confirmed that catch rates were lower during the 2000 fishery and fishermen with a history of fishing yellowtail clearly noted a decline. When the 2001 fishery commenced in August, fishermen noted an absence of fish in the Yellowtail Hole and reported low catches up to early September. Catch rates for yellowtail in 2001 were considered to be much poorer than past years, but more winter flounder and summer flounder were present as bycatch. Fishermen also expressed concern about the high abundance of skates. The presence of summer flounder on the bank may indicate that environmental conditions in 2001 were different (i.e. warmer bottom water temperatures) when the season commenced, and could have resulted in yellowtail temporarily moving out of traditional fishing areas. Alternatively, the reduced catch rates from 2000 to 2001 could simply be a function of a nearly identical catch taken with twice as much effort.

During the May 2004 industry consultation, fishermen indicated that catch rates have been low for the past three years (2001-2003), despite a very modest increase in 2002. Although the standardized series provides useful anecdotal information on recent trends in the Canadian commercial fishery catch rates, it is not used as a tuning index for the surplus production or VPA models. This is because the catch rate series represents relative abundance from only a small geographic area on the Canadian side of the management unit. A comparable CPUE series from the USA fishery in combination with the Canadian series would be required in order to develop indices which represent the entire management area.

Research Vessel Surveys

Bottom trawl surveys are conducted annually on Georges Bank by DFO in the spring (February) and by the United States National Marine Fisheries Service (NMFS) in the spring (April) and fall (October). Both agencies use a stratified random design, though different strata boundaries are defined (Fig. 20). NMFS spring and fall bottom trawl survey catches (strata 13-21), NMFS scallop survey catches (scallop strata 54, 55, 58-72, 74), and DFO spring bottom trawl survey catches (strata 5Z1-5Z4) were used to estimate relative stock biomass and relative abundance at age for Georges Bank yellowtail. Conversion coefficients, which compensate for survey door, vessel, and net changes in NMFS groundfish surveys (1.22 for old doors, 0.85 for the Delaware II, and 1.76 for the 'Yankee 41' net; Rago et al. 1994) were applied to the catch of each tow.

For all three groundfish surveys, the recent distribution of catches was generally less extensive than the previous five year period (Fig. 21). While the 2004 DFO survey continued to show good catches on the Canadian side in the "Yellowtail Hole" (Stratum 5Z2), there was no sampling in the lower portion of Closed Area II near the international boundary where high catches have often been observed in the past (Stratum 5Z4). Coverage by NMFS surveys is always more sparse than the DFO survey and occasionally can miss sampling of high abundance areas such as the Yellowtail Hole and the lower portion of Closed Area II. In 2004, no tows occurred in traditional high abundance areas (Yellowtail Hole and eastern part of Closed Area II) and generally catches were very low compared to the past 5 years. Catches from the 2003 NMFS fall survey were modest and occurred within the area of average distribution over the past 5 years.

Biomass indices for the three groundfish surveys track each other reasonably well over the past two decades. The DFO survey biomass series followed an increasing trend from 1995 to 2001 (the highest value in the series), then dropped off slightly in 2002 with a further decline in 2003 and 2004 (Table 7, Fig. 22). The current level is still considerably higher than that observed during the mid-1990s, when the stock was in a collapsed state. The NMFS spring series is longer, and tracks the DFO series well during the years of overlap up to 1999, but then shows a decline though to 2001 followed by a sharp increase in 2002 (Table 8, Fig. 22). Similar to the DFO series, the NMFS spring biomass index follows a sharp decline from 2002 to 2004, the lowest value since 1994. The NMFS fall survey, which is the longest running time series, also shows an increase from 1995 to 1999, with a slight drop in 2000 followed by a large increase in 2001 (Table 9, Fig. 22). This series showed a strong decline between 2001 and 2002, with a very slight increase in 2003. The NMFS fall index is still at a relatively high level compared to the mid 1990's when the stock was at low levels. Note that both the NMFS spring and fall survey series showed high inter-annual variability during the previous periods of high abundance, the 1960s and 1970s, which may be reflective of the patchy distribution of yellowtail on Georges Bank.

Since 1996, most of the DFO survey biomass and abundance of yellowtail flounder has occurred in Stratum 5Z4, which includes the lower portion of Closed Area II on the US side where no commercial groundfish fishing has occurred since 1995 (Fig. 23). Although survey estimates for this stratum tend to be quite variable due to low sampling intensity, there was an increasing trend from 1996 to 2003 followed by a sharp decline in 2004. Some of this decline is attributed to reduced sampling of the traditional high abundance area in the eastern part of Closed Area II, since most of the tows for Stratum 5Z4 in 2004 fell either north or south of this region. Stratum 5Z2 (CDN portion of Georges < 90 m depth) has also shown an increasing trend in biomass and abundance since 1996, but at a lower level than 5Z4. The 2004 survey indicates that both biomass and abundance remain high in this area.

Both the NMFS fall and spring survey results have become largely determined by stratum 16 (much of Closed Area II and the Canadian Yellowtail Hole) although earlier in both series strata 13 and 19 were important (Figs. 24 & 25). Since 1994, stratum 16 has on average accounted for 85% and 82% of the total NMFS fall and spring survey indices whereas this stratum accounted for only approximately 40% of the survey indices in years prior to 1980. In both the NMFS fall and spring surveys, stratum 16 is allocated 10 tows, meaning that these two indices are largely determined by a total of 20 tows in any given year. Stratum 16 has three areas with different management regulations during the past decade which would be expected to produce heterogeneous distributions of yellowtail; Closed Area II, areas open to fishing on the US side of the Hague Line, and Canadian waters (including the Yellowtail Hole). The number of tows conducted in each of these areas can be an important determinant of the resulting index for the year.

The effect of areas closed to groundfish fishing on the US portion of Georges Bank (Closed Areas I and II) on the two NMFS surveys was examined by post-stratifying the tows to classify them as having occurred either inside or outside the

boundaries of CAI or CAII. Mean catch per tow in weight was computed separately for tows inside and outside closed area boundaries for the entire time series available and for all strata on Georges Bank (13-21) and stratum 16 alone. For the NMFS fall survey, all strata combined and stratum 16 alone showed similar trends with similar mean catch per tow inside and outside closed area boundaries prior to closure but a more rapid increase in catch per tow inside closed area boundaries following the actual closure of the areas in 1995 (Fig. 26). Early in the fall time series the mean catch per tow was higher inside the closed area boundaries even though the areas were not closed to fishing, demonstrating that this area was a preferred habitat for yellowtail during a period of high abundance. In contrast, while the mean weight per tow for all of Georges Bank showed a similar trend in the spring as it did in the fall, the pattern was reversed for stratum 16 in the spring where the open areas show a higher catch per tow than the closed areas since closure occurred (Fig. 27). The two years causing this non-intuitive result are 1999 and 2003 in which single tows in open areas caused the high values (means would have been 13.8 and 32.2 for 1999 and 2003, respectively, without the individual tows of greater than 100 kg). These results reflect both the patchy distribution of yellowtail on Georges Bank as well as the relatively low sampling in the NMFS fall and spring surveys on Georges Bank.

In spite of the patchiness of yellowtail on Georges Bank, all three surveys do present a common overall impression of abundance, as seen by computing the standardized logarithmic values of catch in numbers at age from each survey (Fig. 28). The standardized values are computed by first taking the logarithm of each non-zero observation (zero observations are treated as missing values in the assessment), because the indices are fit assuming lognormal error structure. The mean of these values for each survey and age combination is then subtracted to produce the values plotted. The trends for all surveys and ages are remarkably similar, although noisy, with high abundance in the 1960s followed by declines into the late 1980s or mid 1990s, a subsequent increase through 2000, and a leveling off or decline in the most recent years. These trends indicate a rebuilding of the population since the mid 1990s, which is corroborated by the proportion of fish ages 6+ in the surveys (Fig. 29). These proportions were computed using the number caught ages 2 and older due to the low selectivity of age 1 yellowtail in these surveys. The simple equilibrium calculations assume full selectivity for ages 2 and older, which is not met for these surveys (age 2 is only partially selected), but provides some context for the increases seen in the observed proportions. The increase in proportion of older fish is an indication of increased recruitment, reduced fishing mortality, or both.

In contrast to the proportion of old fish observed in the surveys, calculation of total mortality rates from the surveys indicate no reduction in mortality over time (Fig. 30). These calculations are clearly noisy, but do not show signs of any interventions or overall changes in total mortality rate during the time series, as would be expected from the management measures implemented in both Canada and the US. This may be due to the inherent noisy nature of these surveys or could reflect ineffective management measures.

The length composition of yellowtail flounder captured in the DFO surveys has been fairly consistent over the past 5 years (2000-2004) with little change in the

average size of each sex (Fig. 31a). During this period, males have averaged 34 cm TL and females have averaged 39-40 cm TL. While no decline in average size is apparent for both sexes, a decline in abundance is clearly evident. The sex ratio increased from 52% males in 2003 to 58% males in 2004, and is comparable to the average of 60% for 2000-2002. The average weights at length were examined by sex for three length ranges of yellowtail flounder (29-31 cm, 34-36 cm and 39-41 cm) for DFO surveys conducted from 1987-1991 and 1996-2004 (note: weights were not recorded for the1992-1995 DFO surveys) (Fig. 31b). This measure, which is used to reflect condition, has not changed appreciably over the past decade, with the exception of a slight decline from 2003-2004 in the larger size categories. This decline is attributed to the timing of the 2004 DFO survey, which began 2 weeks earlier than previous surveys and likely reflects a lower amount of gonadal development compared to other years.

Age-structured indices of abundance for NMFS spring and fall surveys were derived using survey-specific age-length keys. In the past, age-length keys from NMFS spring surveys have been substituted to derive age composition for same-year DFO spring surveys, since no ages were directly available from the DFO surveys because of difficulties associated with age interpretation from otolith sections (Stone and Perley 2002). In 2004, scales were collected during the 2004 DFO survey for age interpretation by the NMFS age reader. A comparison of the 2004 DFO spring survey abundance indices based on ALK's from scales collected during the 2004 DFO survey and aged by the NMFS age reader (n=338) and from scales collected from the 2004 NMFS spring survey applied to DFO survey abundance at length (n=96 + 40 for filling in missing ages) indicates that both methods provide similar results (Fig. 32). Therefore, the ALK based on scales collected from the 2004 DFO survey were used to generate age-specific indices of abundance.

Both the DFO and NMFS spring series show a decline in abundance for ages 2-5 in 2004 with the 2001 year class (age 3) predominant in both surveys (Tables 7-8; Fig. 33). The 2003 NMFS fall survey generally has abundance levels which are comparable to 2002 for all age groups (Table 9; Fig. 33). Similar to the DFO and NMFS spring surveys, the 2001 year class (Age 2) is predominant in the 2003 NMFS fall survey. Overall, age-structured indices from the surveys do not track cohorts well and there are some indications of year-effects within the time series. However there appears to be some consistency with the 2001 year class in the 2003 NMFS fall survey and both 2004 spring surveys.

The NMFS scallop survey is used as an index of "mid-year" age 1 yellowtail recruitment since small yellowtail are a common bycatch in this survey. The time series was updated from the 2003 assessment to include index values for 2003. While the 2003 value shows a slight decrease from 2002, the overall trend is one of increasing age 1 abundance since the early 1990's (Table 10).

ESTIMATION OF STOCK PARAMETERS

Calibration of VPA

The Virtual Population Analysis (VPA) used annual catch at age, $C_{a,t}$, for ages a = 1 to 6+, and time t = 1973 to 2003, where t represents the beginning of the time interval during which the catch was taken. The VPA was calibrated to bottom trawl and scallop survey abundance indices, $I_{s,a,t}$, for:

s = DFO spring, ages a = 2 to 6+, time t = 1987 to 2004
s = NMFS spring (Yankee 36), ages a = 1 to 6+, time t = 1982 to 2004
s = NMFS spring (Yankee 41), ages a = 1 to 6+, time t = 1973 to 1981
s = NMFS fall, ages a = 1 to 6+, time t = 1973.5 to 2003.5
s = NMFS scallop, age a = 1, time t = 1982.5 to 2003.5

Data were aggregated for ages 6 and older to mitigate against frequent zero observations. Two independent sets of software were used for the analyses; the Canadian ADAPT software and the US NFT VPA v2.1.7 software. Results from the two approaches have always been quite similar, but slight differences exist in the minimization routines, treatments of the plus group, and utilization of bias correction. The fishing mortality rate for the 6 plus group was calculated according to the "alpha" method (Restrepo and Legault 1994) in the Canadian ADAPT software, while an average of fishing mortality on younger ages was used in the US NFT VPA software. Canadian scientists and managers have traditionally utilized bias correction in presentation of results, while US scientists and managers have not. Nonetheless, the results have been so similar between the methods that differences often cannot be seen on graphs, but rather must be observed in tables of results.

Both the Canadian and US software packages use the adaptive framework, ADAPT, (Gavaris 1988b) to calibrate the sequential population analysis with the research survey abundance trend results. The model formulation employed assumed that the random error in the catch at age was negligible. The errors in the abundance indices were assumed independent and identically distributed after taking natural logarithms of the values. Zero observations for abundance indices were treated as missing data as the logarithm of zero is not defined. The annual natural mortality rate, M, was assumed constant and equal to 0.2 for all ages. The fishing mortality rates for age groups 5 and 6+ were assumed equal. These model assumptions and methods were similar to those applied in the last assessment (Stone and Legault 2003). Both point estimates and bootstrap statistics of the estimated parameters were derived.

The population abundance estimates show greater relative error in model fit (45%) and relative bias (7%) for age 2 while the relative error for ages 3-5 is lower (31-37%) and the bias is smaller (1-4%) (Table 11). Noteworthy is that the bias for all ages was much lower than estimated from the previous assessment in 2003. Survey calibration constants were slightly higher this year for the DFO survey compared to last year's estimates and indicate a slight increase in catchability. For all other surveys, the calibration constants were similar to the 2003 assessment values. The average magnitude of residuals was large and negative for both the 2004 DFO and NMFS spring

surveys for all ages (i.e. model predicts higher abundance than surveys) (Figs. 34-40). These large negative residuals will impact parameter estimates of current abundance. Retrospective analysis indicates a strong tendency to underestimate fishing mortality on ages 4-5 and to overestimate spawning stock biomass and age 1 recruitment (Fig. 41). These strong retrospective patterns seriously affect the potential to provide reliable estimates of current population abundance, recruitment and projected catch biomass.

Surplus Production Analyses

As was done last year, and recognizing the uncertainties in the age-structured information, an assessment method that does not rely upon age-structured data was also used. The ASPIC non-equilibrium surplus production methodology (Prager 1995) requires total catch and one or more indices of abundance. The indices used were DFO spring survey (1987 to 2004, lagged one year to reflect end of previous year biomass), NMFS spring (1968 to 1972; 1982-2004, lagged one year), and NMFS fall (1963 to 2003). The NMFS spring survey was subdivided into two periods when theYankee-36 trawl was used. The NMFS spring Yankee-41 trawl series (1973-1981) has been omitted from recent assessments since it is not considered to be influential. Yield input includes estimates of USA (1963-2003) but not Canadian discards (which is consistent with the CAA used in the ADAPT formulation). Estimates of initial biomass (B_1), maximum sustainable yield (MSY), intrinsic rate of increase (r), and catchability of each survey (q) were obtained using nonlinear least squares of survey residuals. Following the advice of Prager (1995), the first five years of output from ASPIC are not presented, since the starting biomass in the first year is poorly estimated.

Age Structured Assessment Program

As was done last year, but not reported in the working paper, a forward projecting, statistical catch-at-age model was applied to the data as well. The particular model applied, ASAP (Legault and Restrepo 1999), is available in the NOAA Fisheries Toolbox. It allows for error in the catch at age information and assumes that fishing mortality has two components, a year effect and selectivity at age (which can change over time). This model also allows the tuning indices to be matched to the predicted populations at the time the survey occurs by assuming that fishing occurs consistently throughout the year. Only years 1973 through 2003 were used in the ASAP analyses, for ease of comparison with the VPA results and because ASAP is currently not configured to use tuning information in the terminal year+1.

STOCK STATUS

Virtual Population Analysis

Although there are concerns with the reliability of the CAA and age-specific indices of abundance, the results from the standard lognormal model formulation were used to evaluate the status of the stock in 2003. For each cohort, the terminal population abundance estimates from ADAPT were adjusted for bias and used to construct the history of stock status from the Canadian ADAPT software (Tables 12-13).

Since the percent bias was low for all estimates, the bias corrected estimates are not much different from the non-bias corrected estimates. In the absence of an unbiased point estimator with optimal statistical properties, this approach was considered preferable by Canadian, but not US, scientists and managers. The fishery weights at age, assumed to represent mid-year weights, were used to derive beginning of year weights at age (Table 14), and these were used to calculate beginning of year population biomass (Table 15). In the US, spawning stock biomass is the preferred metric for biomass and is computed assuming maturity at age and the proportion of mortality within a year that occurs prior to spawning (p).

Beginning of year population biomass (Ages 1-6+) declined from about 32,000 t in 1973 to a historic low of about 3,600 t in 1988 and has subsequently increased steadily to over 24,000 t at the beginning of 2004 (Table 15, Fig. 42). Spawning stock biomass follows a similar trend (Fig. 41) with the 2003 SSB of approximately 16,000 t less than half of the Bmsy target of 58,800 t, meaning the stock is considered overfished according to the US Sustainable Fisheries Act. The increasing trend is due principally to improved recruitment from the mid-1990's onward, but was also enhanced by increased survivorship of young yellowtail through reduced exploitation. The biomass of adult fish (ages 3+) shows a similar trend and was estimated at 16,000 t at the beginning of 2004 (Fig. 42). However, these estimates are considerably lower than those from the 2002 assessment (i.e. 1+: 58,000 t, 3+: 42,000 t; Stone 2002) and the 2003 assessment (i.e. 1+: 38,000 t, 3+: 26,000 t; Stone and Legault 2003). Last year, the 2000 year-class was estimated to be 48 million at age 1, the largest since 1980, but it is now estimated to be only 29 million at age 1 (Table 12; Fig. 43). The 2001 year class is estimated to be 35 million recruits and is now the largest since 1980. The 1997 year class, which was estimated to be as high as 72 million recruits (Stone et al. 2001), is now estimated to be only 22 million at age 1. Current indications for the 2002 year class (estimated at 21 million recruits) indicate that it may be of moderate strength, but given the strong retrospective pattern observed in the current and previous assessments, the strength of this year class is likely overestimated. The retrospective pattern was discussed in detail at the 2003 TRAC meeting and some possible sources given as: misrepresentative sampling, incorrect estimation of the natural mortality rate due to sexual dimorphism, and underestimation of catch.

The fully recruited (4+) exploitation rate averaged 58% from 1972-1994, underwent a strong decline in 1995 and is now estimated at 43%, which is well above the 20% exploitation equivalent to $F_{0.1} = F_{MSY}$ proxy of $F_{40\%MSP} = 0.25$ (Fig. 44). The 2003 F estimate of 0.45 is above the F_{MSY} proxy value, meaning the stock is considered to be "undergoing overfishing" by US conservation rules, and has not been below the F_{MSY} proxy during the period 1973 through 2003. This is a substantial difference from the 2002 and 2003 assessments, when age 4+ F was estimated to be below $F_{0.1}$ (i.e. 9% exploitation in 2001 and 18% exploitation in 2002, respectively). Exploitation on age 3 has not decreased proportionately and appears to have increased from 32% in 1996 to 55% in 2001, but then declined again to 33% in 2003. In the current assessment, the age 3 partial recruitment to the fishery appears to have decreased by one half over the past three years (i.e. from 1.000 in 2001 to 0.538 in 2003). Age 3 continues to be exploited more heavily than recommended by the $F_{0.1}$ harvest strategy (current exploitation rate =33%).

Gains in fishable biomass may be partitioned into those associated with somatic growth of yellowtail which have previously recruited to the fishery and those associated with new recruitment to the fishery (Rivard 1980). We used age 2 as a convenient age of first recruitment to the fishery. On average, growth contributes about 50% of total production, ranging from 34-76% since 1973 (Fig. 45). Surplus production is defined as the gains in fishable biomass which are in excess of the needs to offset losses from natural mortality. When the fishery yield is less than the surplus production, there is a net increase in the population biomass. Since 1995, there was considerable production in excess of fishery removals up to 1999. Surplus production declined in 2000, then increased to a very high level in 2002, but has since dropped off again in 2003. The 2003 surplus production was estimated to be at 6,694 t compared to 12,289 t in 2002. The high value observed in 2002 may have been influenced by the strong 2000 year-class. The yield for Age 2+ in 2003 was estimated to be 5,489 t and is similar to 2002.

Surplus Production Analyses

Correlations among survey biomass indices were strong (r= 0.82, 0.84, and 0.90; Appendix A), indicating that the three series track each other quite well. Although much of the variance in survey indices was explained by the model, the r^2 values were considerably lower with the addition of the most recent survey index values (i.e. for NMFS Fall, Spring and DFO surveys, r^2= 0.76, 0.63 and 0.85 for last year *vs* 0.72, 0.43, and 0.68 for this year). There were also some residual patterns, with biomass residuals in the last year being very large and negative for the NMFS spring and DFO surveys (*i.e.* surveys indicate much lower current biomass than the model) and large and positive for the NMFS fall survey. The population biomass in 1963, the starting year for analysis, was estimated to be 42% larger than the ASPIC estimated carrying capacity. The nonlinear solution was sensitive to the starting conditions when default convergence criteria were used (Prager 1995). Therefore, convergence criteria were made more restrictive (same as in previous 2003 assessment). Survey residuals were randomly resampled 500 times for bootstrap estimates of precision and model bias. A large portion (>20%) of bootstrap trials did not meet the convergence criteria, indicating that bootstrap variance is probably underestimated. The bootstrap analysis indicated that MSY, and *r* were very well estimated (the relative interquartile ranges, IQR, were < 7%), but that B_1 and survey *q*'s were more variable (relative IQRs = 7%-17%). Bootstrap calculations of *K*, B_{MSY}, and F_{MSY} were stable (relative IQRs=5-7%), and ratios of current conditions to MSY conditions (F_{2003}/F_{MSY} and B_{2003}/B_{MSY}) were also fairly precise (relative IQRs=5-8%).

ASPIC results indicate that a maximum sustainable yield of 14,040 t can be produced when the stock biomass (B_{MSY}) is 44,130 t at equilibrium. The population biomass in 2004 continues to increase, and is now estimated to be 70,290 t, approaching the ASPIC estimated carrying capacity of 87,720 t. Trends in biomass indicated from the surplus production analyses are very similar to those obtained from the VPA for 1+ biomass up to 1994, but then increase at a faster rate (Figs. 42). Biomass estimates from ASPIC are considerably higher than those from the VPA since 1994. The exploitation rate on total biomass in 2003 (7.3 %) decreased from 2002 (7.6%) and is considered to be low.

The surplus production model attempts to describe long term population dynamics in a simple model which projects past stock productivity forward. However, it is not clear whether past stock productivity will always be a good predictor of stock dynamics. Further, surplus production models may fail to capture the dynamic changes that occur in recruitment, growth and exploitation patterns at age. Simple deterministic projections of this model produce unreasonably large estimates for yield in 2005 (>20,000 t) assuming a similar level of catch is taken in 2004 and the ASPIC estimate of F_{MSY} = 0.32 is applied in 2005.

Age Structured Assessment Program

A number of scenarios were examined using ASAP differentiated by the assumptions made regarding selectivity at age (Fig. 46). A flat-topped selectivity pattern was forced by setting the selectivity at ages 5 and 6+ equal to the selectivity at age 4 (AsapFlat). When the model was allowed to estimate one selectivity at age pattern for all years, a dome resulted (AsapDome). When the model estimated two selectivity patterns, one for years 1973-1993 and the other for 1994-2003, two domes resulted with the more recent dome being stronger (AsapDome2Block). When the model had selectivity fixed as flat-topped for years 1973-1993 but estimated selectivity for the remaining years, a dome for the recent years resulted (AsapFlatThenDome). Finally, when the units for the indices was biomass and all ages were combined (flat-topped selectivity was assumed for each survey selectivity), and the model estimated fleet selectivity, a strong dome resulted (AsapBindex).

The reason for exploring a dome-shaped selectivity pattern was the hypothesis that Closed Area II has acted like a refuge for old fish, thereby reducing the selectivity on these fish. Andrew Applegate (NEFMC) presented a working paper at the TRAC meeting demonstrating a change in average length inside area covered by CAII after it was closed to fishing in 1995 for the fall NEFSC survey. This change in mean length was not observed outside the boundary of CAII, implying a change in relative vulnerability to fishing gear if the fish do not move across the boundary. However, this relative change in vulnerability inside vs outside CAII was ~~not~~ apparent in the NEFSC spring survey.

In general, the results of the different ASAP runs were quite similar and intermediate between the VPA and ASPIC results (Fig. 47). Retrospective patterns were observed that were similar in direction, but much less in magnitude, to those observed in the VPA results (Fig. 48). Note that in all the comparisons between ASAP and VPA results, the metrics for F and SSB are different between the two models; VPA uses ages 4-5 F and SSB during the year while ASAP uses fully selected F and SSB at the start of the year. However, the trends can still be compared between the models.

FISHERY REFERENCE POINTS

Yield per Recruit Reference Points

Although the yield per recruit analysis was not updated this year, an estimate of $F_{0.1}$ for ages 4+ was calculated based on the equilibrium age structure from the past yield per recruit analysis of Neilson and Cadrin (1998). ($F_{0.1}$ for ages 4+ = 0.25; exploitation rate=20.0%). This is the same value as the F_{MSY} proxy of $F_{40\%MSP}$ used for US management (NEFSC 2002).

Stock and Recruitment

There is evidence of reduced recruitment at low levels of age 3+ biomass (Fig. 49). However, management actions by both countries appear to have been successful in building the population to levels where the probability of good recruitment may be enhanced. Based on the spawning stock biomass and recruitment relationship observed in a previous stock assessment, the B_{MSY} level of 58,800 t of spawning stock biomass was set as the rebuilding goal in the US for this stock (NEFSC 2002). Note that in the ASAP results, both F_{MSY} and B_{MSY} are calculated for each model run using the estimated stock-recruitment relationship and age-based information from 2003.

Current Status

The current status of Georges Bank yellowtail flounder can be determined from each of the multiple analyses conducted and compared by computing the ratio of current F and B to the management levels desired. For example, if the US management scheme of F_{MSY} and B_{MSY} is used as the reference point, then F and SSB in 2003 can be divided by these reference values and plotted on a single graph even though the F_{MSY} and B_{MSY} values differ in the different analyses (Fig. 50). In this figure, points that fall above the $F/F_{MSY} = 1$ line are undergoing overfishing, points that fall to the left of the $B/B_{MSY} = 0.5$ line are overfished, and points that fall to the right of the $B/B_{MSY} = 1$ line are fully rebuilt. The different analyses produce quite different assessments of current status, with results located in four of the six possible areas. The two traditional assessment methods (AdaptBase and AspicBase) produce opposite results, with the VPA estimating current status as overfished and undergoing overfishing while the surplus production model estimates current status as underutilized. As noted previously, the ASAP results are intermediate to these two results. The distribution of points in the plot demonstrate that a given catch can be explained by many possible combinations of F and B which are inversely related such that either the stock is high and F is low, or vice versa.

Some sensitivity analyses for the VPA are also presented in the figure which drop either just the NMFS spring 2004 index values or else drop both the NMFS spring and DFO 2004 index values. These sensitivity runs produce more optimistic results than the VPA base case, demonstrating the influence of the low NMFS spring and DFO survey values in 2004. Two other VPA sensitivity runs are presented in the figure. These runs force a dome shaped selectivity pattern by changing the ages used to estimate the oldest age in the NMFS NFT VPA software. AdaptDome has a strong

dome shaped partial recruitment pattern imposed by estimating Foldest as the average of F at ages 2 to 3, while AdaptDome2 has a less strong dome by averaging F at ages 2 to 4. These results are presented in the plot assuming the same F_{MSY} and B_{MSY} as the VPA base case, which is incorrect as new values would need to be calculated. These two runs are presented to demonstrate that VPA can produce widely different results if different assumptions are made about the selectivity at older ages (Fig. 51), but are not recommended as replacements for the base case.

OUTLOOK

While the historical population reconstruction from the VPA and the surplus production model show concurrence up to 1995, current stock status and projections from the two models diverge significantly. The projection results from the surplus production model imply high equilibrium recruitment levels that are not consistent with historical estimates. Accordingly, the ASPIC projection results are not considered reliable.

Given the wide range of uncertainty in current status from the VPA and ASAP model results, only deterministic projections were conducted as the uncertainty between models was thought to be greater than the uncertainty within any one model. The deterministic projections were conducted in a spreadsheet for a range of initial population abundances at age, catch levels in 2004, and partial recruitment vectors. For example, the VPA base case numbers at age in 2004 from the US NFT VPA software are used as the initial population size and the catch in 2004 is assumed to be 6,000 t, and the flat-topped partial recruitment vector from the VPA used, then the expected catch in 2005 if fishing occurs at $F_{ref} = 0.25$ is 4,422 t (Table 16).

In all the projections, the abundance of the 2004 and 2005 year-classes were assumed to be 20 million at age 1, lower than the value of 30 million used in the 2003 assessment. However, this choice has only a small impact on the predicted catch in 2005. For example, in the case described in the previous paragraph, using 30 million recruits for years 2004 and 2005 would result in a 2005 catch of 4,596 t, a change of less than 4%. Fishery weights at age and beginning of year population weights at age were averaged over the previous 5 years (1999 through 2003) for use in the 2005 forecasts. Maturity at age and the fraction of the year before spawning, for calculations of spawning stock biomass, were assumed equal to the 2003 values.

Three different initial populations in 2004 were used for deterministic projections; the VPA base case from US NFT VPA software, the ASAP run which assumed a flat-topped selectivity pattern for years 1973-1993 and estimated a dome pattern in years 1994-2003 (AsapFtD), and the ASAP run which estimated selectivity in two blocks 1973-1993 and 1994-2003 (AsapD2Block). These cases were chosen to span the range of estimated current status. The partial recruitment for the ADAPT run was flat-topped, while the two ASAP runs used either this same flat-topped selectivity pattern or else the pattern estimated within ASAP for projections. A range of 5,000 to 10,000 t yield in 2004 was projected for each of the five cases (Fig 52 and Table 17). A wide range of yield in 2005 is projected from these five cases. For example, if the yield in 2004 is 6,000 t, then

the projected yield in 2005 under F = 0.25 ranges from 4,422 to 9,847 t. The ADAPT case is the most pessimistic projection due to its low starting abundance in 2004. The ASAP projections that assume a dome for the recent years, but then use a flat-top selection pattern for projections, produce the highest yields in 2005. This scenario could happen if the closed areas were creating a refuge for old fish, and thus a dome in the assessment, and then were opened, removing the refuge and causing a flat-topped selection pattern in the projections. These yields assume there has been an accumulation of old fish and would require low fishing mortality rates and/or high recruitment in the future to allow them to continue.

The population age structure has improved only slightly in recent years although population biomass appears to have increased. The current age structure indicates that very little rebuilding of ages 4 and 5 has occurred and that the population is still dominated by younger ages 1 through 3 according to the VPA (Fig. 53). In addition, the VPA estimates far fewer older fish (6+) in comparison with a population at equilibrium, which is inconsistent with the perception of recent low exploitation. In contrast, all the ASAP runs estimate much larger abundances, especially in the oldest ages.

MANAGEMENT CONSIDERATIONS

This assessment is hampered by inconsistencies between the age structure of the catch and the age-specific indices of abundance. Although the catch of old fish has increased in the most recent year, it is still less than would be expected given the increases seen in the age-specific indices of abundance. The noisy character of the indices cause difficulty in tuning age structured models.

The outlook is even more uncertain this year than last year due to an increase in the retrospective pattern seen in the VPA assessments for 2003 and 2004 and divergence between the VPA and production model results. The ASAP results are intermediate between the VPA and surplus production model results. However, the wide range of 2005 yield from deterministic projections of the VPA and ASAP results mean that the different stock status estimates have a direct impact on management decisions. While the proportion of the catch comprised of older fish is increasing in the US, it is not in Canada. Low sampling of landings back in time along with borrowing of age-length keys creates uncertainty in the catch at age for earlier years, but is not thought to be as large a problem in recent years when sampling has increased. The indices are in general increasing in recent years, but the most recent year values are low. Survey indices at age all show increasing trends since the late 1980s or mid 1990s, but are noisy. The survey total mortality estimates are also noisy, but do not show a decrease in recent years. Ongoing tagging studies may provide independent estimates of mortality that could help distinguish among the possible models. Canadian discards have not been incorporated into the assessment. The impact of including this source of mortality on stock status is not known. Fish caught inside Closed Area II appear to be larger, and are therefore presumably older, than in the open areas, which could potentially cause a dome shaped selectivity pattern if yellowtail remain in the closed area for long periods of time. However, a special access program (SAP) for yellowtail flounder in CAII began

June 1, 2004 and may harvest any surplus that has accumulated there. Similarly, a SAP for the US scallop fleet is under consideration in CAII, which could produce increased US discards of yellowtail flounder. Recruitment appears to be increasing, but is not well estimated by any method in the most recent years. Considering all these sources of uncertainty in the stock assessment, status quo catch or lower may be an appropriate management approach until these issues are resolved. This is of particular importance since at present, it not clear if any of the management objectives are being met for this stock.

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Table 1. Annual catch (000s t) of Georges Bank yellowtail flounder. Canadian landings have been adjusted for catches of unspecified flounder. Estimates for discards from the Canadian offshore scallop fishery prior to 1996 are not available.

Year	US landings	US discards	Canadian landings	Canadian discards	Foreign Catch	Total Catch
1963	10.990	5.600	-	-	0.100	16.690
1964	14.914	4.900	-	-	0.000	19.814
1965	14.248	4.400	-	-	0.800	19.448
1966	11.341	2.100	-	-	0.300	13.741
1967	8.407	5.500	-	-	1.400	15.307
1968	12.799	3.600	0.004	-	1.800	18.203
1969	15.944	2.600	0.030	-	2.400	20.974
1970	15.506	5.533	0.011	-	0.250	21.300
1971	11.878	3.127	0.018	-	0.503	15.526
1972	14.157	1.159	0.000	-	2.243	17.559
1973	15.899	0.364	.002	-	0.260	16.525
1974	14.607	0.980	0.002	-	1.000	16.589
1975	13.205	2.715	0.000	-	0.091	16.011
1976	11.336	3.021	0.000	-	0.000	14.357
1977	9.444	0.567	0.003	-	0.000	10.014
1978	4.519	1.669	0.003	-	0.000	6.191
1979	5.475	0.720	0.004	-	0.000	6.199
1980	6.481	0.382	0.007	-	0.000	6.870
1981	6.182	0.095	0.001	-	0.000	6.278
1982	10.621	1.376	0.000	-	0.000	11.997
1983	11.350	0.072	0.000	-	0.000	11.422
1984	5.763	0.028	0.003	-	0.000	5.794
1985	2.477	0.043	0.000	-	0.000	2.520
1986	3.041	0.019	0.015	-	0.000	3.075
1987	2.742	0.233	0.055	-	0.000	3.030
1988	1.866	0.252	0.042	-	0.000	2.160
1989	1.134	0.073	0.018	-	0.000	1.225
1990	2.751	0.818	0.009	-	0.000	3.578
1991	1.784	0.246	0.047	-	0.000	2.077
1992	2.859	1.873	0.036	-	0.000	4.768
1993	2.089	1.089	0.675	-	0.000	3.886
1994	1.589	0.141	2.139	-	0.000	3.890
1995	0.292	0.024	0.501	-	0.000	0.817
1996	0.751	0.039	0.483	0.177	0.000	1.450
1997	0.966	0.058	0.810	0.195	0.000	2.029
1998	1.822	0.114	1.175	0.296	0.000	3.407
1999	1.987	0.484	1.971	0.181	0.000	4.623
2000	3.678	0.358	2.859	0.116	0.000	7.011
2001	3.792	0.505	2.913	0.814	0.000	8.024
2002	2.532	0.466	2.642	0.457	0.000	6.097
2003	3.343	0.271	2.107	1.086	0.000	6.807

Table 2. Port samples used in the estimation of landings at age for Georges Bank yellowtail flounder in 2003 from Canadian and US sources.

USA		Port Samples			Sea Samples			Landings
Quarter	Size	Trips	Lengths	Ages	Trips	Lengths	Ages	(t)
1	All	14	1,257	274	26	1,173	0	908
2	All	13	1,515	366	31	1,780	0	1,184
3	All	6	808	196	19	532	0	318
4	All	13	1,297	280	20	711	0	933
All	All	46	4,877	1,116	96	4,196	0	3,343
Canada		**Port Samples**			**Sea Samples**			**Landings**
Quarter	Size	Trips	Lengths	Ages	Trips	Lengths	Ages	(t)
1	0	0	0	0	0	0	0	0
2	All	5	1,066	0	3	1,597	0	365
3	All	17	3,719	0	3	2,532	0	1,331
4	All	5	1,158	0	3	1,836	0	374
All	All	27	5,943	0	9	5,965	0	2,070

Table 3. Number of fish caught by sex and area during a tagging program conducted July 2003 (data kindly provided by S. Cadrin, NMFS).

Area	Female	Male	Total	% Female
522	563	153	716	79%
525	129	10	139	93%
562	2,940	20	2,960	99%
Total	3,632	183	3,815	95%

Table 4. Total catch at age (Canada + USA; number in 000's) including US discards but not including Canadian discards, for Georges Bank yellowtail flounder, 1973-2003.

	Age								
Year	1	2	3	4	5	6	7	8+	Total
1973	347	4890	13243	9276	3743	1259	278	81	33117
1974	2143	8971	7904	7398	3544	852	452	173	31437
1975	4372	25284	7057	3392	2084	671	313	164	43337
1976	615	31012	5146	1347	532	434	287	147	39520
1977	330	8580	9917	1721	394	221	129	124	21416
1978	9659	3105	4034	1660	459	102	37	35	19091
1979	233	9505	3445	1242	550	141	79	52	15247
1980	309	3572	8821	1419	321	85	4	10	14541
1981	55	729	5351	4556	796	122	4	0	11613
1982	2063	17491	7122	3246	1031	62	19	3	31037
1983	696	7689	16016	2316	625	109	10	8	27469
1984	428	1917	4266	4734	1592	257	47	17	13258
1985	650	3345	816	652	410	60	5	0	5938
1986	158	5771	978	347	161	52	16	8	7491
1987	140	2653	2751	761	132	39	32	41	6549
1988	483	2367	1191	624	165	15	20	3	4868
1989	185	1516	668	262	68	11	8	0	2718
1990	219	1931	6123	800	107	17	3	0	9200
1991	412	54	1222	2430	293	56	4	0	4471
1992	2389	8359	2527	1269	510	20	7	0	15081
1993	5194	1009	2777	2392	318	65	9	1	11765
1994	71	861	5742	2571	910	99	37	1	10292
1995	14	157	895	715	137	13	11	4	1946
1996	50	383	1509	716	167	9	5	1	2840
1997	16	595	1258	1502	341	26	45	19	3802
1998	26	971	2792	1824	624	82	20	0	6871
1999	21	3287	3209	1498	651	137	25	0	8828
2000	100	3731	5747	2824	798	273	33	18	13524
2001	216	2754	6865	2586	1007	248	207	23	13907
2002	43	4070	3924	1891	719	186	128	66	11027
2003	27	2842	4181	2084	735	267	174	127	10438

Table 5. Mean weight at age (kg) for the total catch, including US discards but not including Canadian discards, of Georges Bank yellowtail flounder.

	Age							
Year	1	2	3	4	5	6	7	8+
1973	0.100	0.352	0.462	0.527	0.603	0.689	1.067	1.136
1974	0.108	0.345	0.498	0.609	0.680	0.725	0.906	1.249
1975	0.111	0.316	0.489	0.554	0.618	0.687	0.688	0.649
1976	0.106	0.312	0.542	0.636	0.741	0.814	0.852	0.866
1977	0.109	0.342	0.525	0.634	0.782	0.865	1.036	1.013
1978	0.100	0.315	0.510	0.684	0.793	0.899	0.930	0.948
1979	0.103	0.331	0.460	0.649	0.728	0.835	1.003	0.882
1980	0.100	0.325	0.493	0.656	0.813	1.054	1.256	1.214
1981	0.099	0.347	0.490	0.603	0.707	0.798	0.832	-
1982	0.112	0.301	0.486	0.650	0.748	1.052	1.024	1.311
1983	0.139	0.296	0.440	0.604	0.736	0.952	1.018	0.987
1984	0.162	0.240	0.378	0.500	0.642	0.738	0.944	1.047
1985	0.178	0.363	0.497	0.647	0.733	0.819	0.732	-
1986	0.176	0.342	0.540	0.664	0.823	0.864	0.956	1.140
1987	0.112	0.316	0.522	0.666	0.680	0.938	0.793	0.788
1988	0.100	0.325	0.555	0.688	0.855	1.054	0.873	1.385
1989	0.100	0.345	0.542	0.725	0.883	1.026	1.254	-
1990	0.100	0.293	0.397	0.577	0.697	0.807	1.230	-
1991	0.100	0.268	0.368	0.481	0.726	0.820	1.306	-
1992	0.100	0.295	0.369	0.522	0.647	1.203	1.125	-
1993	0.100	0.287	0.376	0.507	0.562	0.882	1.038	1.044
1994	0.150	0.256	0.350	0.472	0.628	0.848	0.896	1.166
1995	0.155	0.249	0.365	0.462	0.582	0.703	0.785	0.531
1996	0.137	0.298	0.405	0.568	0.725	0.910	1.031	1.209
1997	0.155	0.310	0.410	0.523	0.668	0.869	0.919	1.216
1998	0.185	0.333	0.453	0.542	0.670	0.829	0.886	-
1999	0.210	0.374	0.506	0.637	0.748	0.873	0.892	1.104
2000	0.185	0.379	0.480	0.612	0.756	0.933	1.001	1.278
2001	0.108	0.287	0.435	0.610	0.812	0.928	0.987	1.236
2002	0.169	0.361	0.484	0.663	0.833	0.994	1.051	1.324
2003	0.194	0.384	0.487	0.646	0.815	0.993	1.120	1.289

Table 6. ANOVA results from a multiplicative model with main effects for year (1993-2003) month (June-Dec) and tonnage class (TC1-3) for the Canadian yellowtail flounder fishery CPUE.

REGRESSION OF MULTIPLICATIVE MODEL

MULTIPLE R..... 0.782
MULTIPLE R SQUARED..... 0.612

ANALYSIS OF VARIANCE

SOURCE OF VARIATION	DF	SUMS OF SQUARES	MEAN SQUARES	F-VALUE
INTERCEPT	1	2.034E3	2.034E3	
REGRESSION	18	4.184E2	2.325E1	120.964
YEAR	10	3.905E2	3.905E1	203.211
MONTH	6	2.978E1	4.963E0	25.826
TONNAGE CLASS	2	1.099E0	5.494E-1	2.859
RESIDUALS	1381	2.654E2	1.922E-1	
TOTAL	1400	2.716E3		

PREDICTED CATCH RATE

	LN TRANSFORM		RETRANSFORMED			
YEAR	MEAN	S.E.	MEAN	S.E.	CATCH	EFFORT
1993	-1.3737	0.0253	0.275	0.044	111	403
1994	-2.1719	0.0018	0.125	0.005	1138	9079
1995	-1.1502	0.0051	0.348	0.025	370	1064
1996	-0.6291	0.0053	0.585	0.043	369	630
1997	-0.5739	0.0032	0.619	0.035	723	1168
1998	-0.6914	0.0026	0.551	0.028	1094	1987
1999	-0.3878	0.0017	0.746	0.030	1871	2507
2000	-1.0429	0.0012	0.388	0.013	2673	6893
2001	-1.6778	0.0012	0.206	0.007	2747	13367
2002	-1.5591	0.0012	0.231	0.008	2543	10989
2003	-1.6717	0.0020	0.207	0.009	1544	7471

RESIDUALS

Table 7. Canadian DFO spring survey indices of Georges Bank yellowtail flounder abundance at age (stratified mean #/tow) and stratified total biomass (000s t).

	Age							Biomass
Year	1	2	3	4	5	6+	Total	(000s t)
1987	0.12	0.68	2.00	1.09	0.06	0.00	3.95	1.264
1988	0.00	0.66	1.89	0.80	0.59	0.01	3.96	1.235
1989	0.11	0.78	0.80	0.32	0.10	0.02	2.13	0.471
1990	0.00	1.27	4.62	1.12	0.43	0.01	7.45	1.578
1991	0.02	0.59	1.72	2.91	0.99	0.00	6.24	1.759
1992	0.22	10.04	4.52	1.21	0.16	0.00	16.14	2.475
1993	0.33	2.16	5.04	3.47	0.62	0.00	11.63	2.642
1994	0.00	6.03	3.33	3.08	0.75	0.33	13.51	2.753
1995	0.21	1.31	4.07	2.22	1.14	0.11	9.07	2.027
1996	0.45	5.54	8.44	7.49	1.37	0.16	23.45	5.304
1997	0.10	9.48	15.16	19.09	3.11	0.54	47.49	13.292
1998	0.92	3.10	3.81	5.15	2.44	0.59	16.01	4.292
1999	0.22	13.05	24.78	9.07	6.85	3.10	57.07	17.666
2000	0.06	9.18	31.22	18.56	5.77	4.42	69.22	19.948
2001	0.29	5.97	51.67	16.65	4.41	3.61	82.62	22.157
2002	0.10	9.30	33.10	11.41	6.75	1.95	62.61	20.624
2003	0.02	9.14	27.11	10.39	2.71	2.31	53.09	16.249
2004	0.03	3.52	15.76	8.96	2.22	1.38	31.88	8.808

Table 8. NMFS spring survey indices (stratified mean #/tow) of Georges Bank yellowtail flounder abundance at age and total biomass (stratified mean kg/tow).

	Age									Biomass
Year	1	2	3	4	5	6	7	8+	Total	kg/tow
1968	0.149	3.364	3.579	0.316	0.084	0.160	0.127	-	7.779	2.813
1969	1.015	9.406	11.119	3.096	1.423	0.454	0.188	0.057	26.758	11.170
1970	0.093	4.485	6.030	2.422	0.570	0.121	0.190	-	13.911	5.312
1971	0.791	3.335	4.620	3.754	0.759	0.227	0.050	0.029	13.564	4.607
1972	0.138	7.136	7.198	3.514	1.094	0.046	0.122	-	19.247	6.450
1973	1.931	3.266	2.368	1.063	0.410	0.173	0.023	0.020	9.254	2.938
1974	0.316	2.224	1.842	1.256	0.346	0.187	0.085	0.009	6.265	2.719
1975	0.420	2.939	0.860	0.298	0.208	0.068	-	0.013	4.806	1.676
1976	1.034	4.368	1.247	0.311	0.196	0.026	0.048	0.037	7.268	2.273
1977	-	0.671	1.125	0.384	0.074	0.013	-	-	2.267	0.999
1978	0.936	0.798	0.507	0.219	0.026	-	0.008	-	2.494	0.742
1979	0.279	1.933	0.385	0.328	0.059	0.046	0.041	-	3.072	1.227
1980	0.057	4.644	5.761	0.473	0.057	0.037	-	-	11.030	4.456
1981	0.012	1.027	1.779	0.721	0.205	0.061	-	0.026	3.830	1.960
1982	0.045	3.742	1.122	1.016	0.455	0.065	-	0.026	6.472	2.500
1983	-	1.865	2.728	0.531	0.123	0.092	0.061	0.092	5.492	2.642
1984	-	0.093	0.809	0.885	0.834	0.244	-	-	2.865	1.646
1985	0.110	2.198	0.262	0.282	0.148	-	-	-	3.000	0.988
1986	0.027	1.806	0.291	0.056	0.137	0.055	-	-	2.372	0.847
1987	-	0.128	0.112	0.133	0.053	0.055	-	-	0.480	0.329
1988	0.078	0.275	0.366	0.242	0.199	0.027	-	-	1.187	0.566
1989	0.047	0.424	0.740	0.290	0.061	0.022	0.022	-	1.605	0.729
1990	-	0.065	1.108	0.393	0.139	0.012	0.045	-	1.762	0.699
1991	0.435	-	0.254	0.675	0.274	0.020	-	-	1.659	0.631
1992	-	2.010	1.945	0.598	0.189	-	-	-	4.742	1.566
1993	0.046	0.290	0.500	0.317	0.027	-	-	-	1.180	0.482
1994	-	0.621	0.638	0.357	0.145	0.043	-	-	1.804	0.660
1995	0.040	1.180	4.810	1.490	0.640	0.010	-	-	8.170	2.579
1996	0.030	0.990	2.630	2.700	0.610	0.060	-	-	7.020	2.853
1997	0.019	1.169	3.733	4.081	0.703	0.134	-	-	9.837	4.359
1998	-	2.081	1.053	1.157	0.759	0.323	0.027	-	5.400	2.324
1999	0.050	4.746	10.820	2.720	1.623	0.426	0.329	0.024	20.738	9.307
2000	0.183	4.819	7.666	2.914	0.813	0.422	0.102	-	16.916	6.696
2001	0	2.315	6.563	2.411	0.483	0.352	0.101	0	12.225	5.006
2002	0.188	2.412	12.333	4.078	1.741	0.378	0.408	0.086	21.624	9.563
2003	0.202	4.370	6.764	2.876	0.442	0.128	0.536	0.198	15.515	6.721
2004	0.049	0.986	2.178	0.680	0.283	0.110	0.052	0.082	4.420	1.887

Table 9. NMFS fall survey indices (stratified mean #/tow) of Georges Bank yellowtail flounder abundance at age and total biomass (stratified mean kg/tow).

	Age										Biomas
	0	1	2	3	4	5	6	7	8+	Total	kg/tow
1963	-	14.722	7.896	11.226	1.858	0.495	0.281	0.034	0.233	36.746	12.788
1964	-	1.721	9.723	7.370	5.998	2.690	0.383	0.095	0.028	28.007	13.623
1965	0.014	1.138	5.579	5.466	3.860	1.803	0.162	0.284	0.038	18.345	9.104
1966	1.177	8.772	4.776	2.070	0.837	0.092	0.051	-	-	17.775	3.988
1967	0.106	9.137	9.313	2.699	1.007	0.309	0.076	0.061	-	22.708	7.575
1968	-	11.782	11.946	5.758	0.766	0.944	0.059	-	-	31.254	10.536
1969	0.135	8.106	10.381	5.855	1.662	0.553	0.149	0.182	-	27.023	9.279
1970	1.048	4.610	5.133	3.144	1.952	0.451	0.063	0.017	-	16.417	4.979
1971	0.025	3.627	6.949	4.904	2.248	0.551	0.234	0.024	0.024	18.586	6.365
1972	0.785	2.424	6.525	4.824	2.095	0.672	0.279	-	-	17.604	6.328
1973	0.094	2.494	5.497	5.104	2.944	1.216	0.416	0.171	0.031	17.996	6.602
1974	1.030	4.623	2.854	1.524	1.060	0.460	0.249	0.131	-	12.133	3.733
1975	0.361	4.625	2.511	0.877	0.572	0.334	0.033	-	0.031	9.420	2.365
1976	-	0.336	1.929	0.475	0.117	0.122	0.033	-	0.067	3.078	1.533
1977	-	0.928	2.161	1.649	0.618	0.113	0.056	0.036	0.016	5.614	2.829
1978	0.037	4.729	1.272	0.773	0.406	0.139	0.011	-	0.024	7.443	2.383
1979	0.018	1.312	1.999	0.316	0.122	0.138	0.038	0.064	0.007	4.041	1.520
1980	0.078	0.761	5.086	6.050	0.678	0.217	0.162	0.006	0.033	13.217	6.722
1981	-	1.584	2.333	1.630	0.500	0.121	0.083	0.013	-	6.345	2.621
1982	-	2.424	2.185	1.590	0.423	0.089	-	-	-	6.711	2.270
1983	-	0.109	2.284	1.914	0.473	0.068	0.012	-	0.038	4.898	2.131
1984	0.012	0.661	0.400	0.306	2.428	0.090	0.029	-	0.018	3.944	0.593
1985	0.010	1.350	0.560	0.160	0.040	0.080	-	-	-	2.200	0.709
1986	-	0.280	1.110	0.350	0.070	-	-	-	-	1.810	0.820
1987	-	0.113	0.390	0.396	0.053	0.079	-	-	-	1.031	0.509
1988	0.011	0.019	0.213	0.102	0.031	-	-	-	-	0.376	0.171
1989	0.027	0.248	1.992	0.774	0.069	0.066	-	-	-	3.176	0.977
1990	0.147	-	0.326	1.517	0.280	0.014	-	-	-	2.284	0.725
1991	-	2.100	0.275	0.439	0.358	-	-	-	-	3.172	0.730
1992	-	0.151	0.396	0.712	0.162	0.144	0.027	-	-	1.592	0.576
1993	-	0.842	0.136	0.587	0.536	-	-	-	-	2.101	0.545
1994	0.010	1.200	0.220	0.980	0.710	0.260	0.030	0.030	-	3.440	0.897
1995	0.070	0.280	0.120	0.350	0.280	0.050	0.010	-	-	1.160	0.354
1996	-	0.140	0.350	1.870	0.450	0.070	-	-	-	2.880	1.303
1997	-	1.392	0.533	3.442	2.090	1.071	0.082	-	-	8.611	3.781
1998	-	1.900	4.817	4.202	1.190	0.298	0.055	0.019	-	12.481	4.347
1999	-	3.090	8.423	5.527	1.432	1.436	0.260	-	-	20.168	7.973
2000	0.019	0.629	1.697	4.814	2.421	0.948	0.800	0.027	-	11.355	5.838
2001	0.037	3.518	6.268	8.091	2.601	1.718	0.714	1.344	-	24.282	11.553
2002	0.052	2.066	5.751	2.127	0.594	0.277	0.000	0.000	0.027	10.841	3.754
2003	1.102	5.006	2.809	0.565	0.100	0.092	0.075	0.025	1.102	9.774	4.039

Table 10. NMFS scallop survey index (stratified mean #/tow) for Georges Bank yellowtail flounder age-1 abundance.

Year	Number per tow
1982	0.313
1983	0.140
1984	0.233
1985	0.549
1986	0.103
1987	0.047
1988	0.116
1989	0.195
1990	0.100
1991	2.117
1992	0.167
1993	1.129
1994	1.503
1995	0.609
1996	0.508
1997	1.062
1998	1.872
1999	1.038
2000	0.912
2001	0.789
2002	1.005
2003	0.880

Table 11. Statistical properties of estimates for population abundance and survey calibration constants ($x10^3$) for Georges Bank yellowtail flounder using Canadian ADAPT software.

		Bootstrap			
Age	Estimate	Standard Error	Relative Error	Bias	Relative Bias
Population Abundance					
2	18985	8514	0.448	1310.949	0.069
3	22363	8206	0.367	921.891	0.041
4	9739	3635	0.373	233.065	0.024
5	2157	659	0.306	19.129	0.009
Survey Calibration Constants					
DFO Survey: 1987-2004 (Age 2-6+)					
2	0.281	0.064	0.227	0.006	0.022
3	1.025	0.219	0.214	0.038	0.037
4	1.535	0.325	0.212	0.034	0.022
5	1.733	0.365	0.211	0.022	0.013
6	1.955	0.480	0.245	0.041	0.021
NMFS Spring Survey: Yankee 41, 1973-1981 (Age 1-6+)					
1	0.008	0.003	0.334	0.001	0.064
2	0.083	0.025	0.301	0.005	0.055
3	0.106	0.032	0.302	0.005	0.044
4	0.104	0.033	0.320	0.005	0.044
5	0.083	0.027	0.327	0.003	0.041
6	0.084	0.024	0.281	0.003	0.030
NMFS Spring Survey: Yankee 36, 1982-2004 (Age 1-6+)					
1	0.004	0.001	0.237	0.000	0.017
2	0.087	0.016	0.180	0.001	0.014
3	0.216	0.039	0.183	0.004	0.018
4	0.306	0.058	0.189	0.009	0.029
5	0.411	0.077	0.186	0.007	0.017
6	0.642	0.133	0.207	0.006	0.010
NMFS Fall Survey: 1973-2003 (Age 1-6+)					
1	0.051	0.008	0.151	0.001	0.016
2	0.116	0.018	0.155	0.000	-0.002
3	0.245	0.040	0.162	0.003	0.013
4	0.271	0.042	0.155	0.003	0.013
5	0.346	0.062	0.179	0.003	0.009
6	0.465	0.091	0.195	0.010	0.022
Scallop: 1982-2003 (Age 1)					
1	0.036	0.007	0.195	0.001	0.031

Table 12. Beginning of year population abundance numbers (000's) for Georges Bank yellowtail flounder from a virtual population analysis using the bootstrap bias adjusted population abundance at the beginning of 2004 from Canadian ADAPT software.

Year	Age Group								
	1	2	3	4	5	6+	1+	2+	3+
1973	27857	22950	28577	16854	6801	2940	105977	78120	55171
1974	49338	22494	14392	11572	5543	2310	105649	56311	33817
1975	67297	38460	10389	4748	2917	1607	125418	58122	19662
1976	22618	51153	9102	2265	895	1460	87492	64875	13721
1977	15642	17963	14350	2875	658	792	52280	36638	18675
1978	50294	12509	7049	2986	826	313	73976	23682	11173
1979	23135	32486	7451	2185	967	478	66703	43568	11082
1980	21884	18731	18066	3024	684	211	62600	40717	21986
1981	59983	17638	12121	6922	1209	191	98065	38082	20444
1982	21271	49060	13782	5143	1633	133	91023	69752	20692
1983	5753	15555	24496	4937	1332	271	52344	46592	31036
1984	8501	4083	5878	5872	1975	398	26706	18205	14123
1985	14338	6574	1631	1051	661	105	24360	10022	3448
1986	6564	11152	2400	608	282	133	21140	14576	3423
1987	6957	5232	3988	1090	189	160	17617	10660	5428
1988	19080	5569	1918	834	220	51	27673	8593	3023
1989	8446	15185	2443	514	133	37	26759	18313	3128
1990	11555	6748	11066	1401	187	35	30991	19437	12689
1991	21632	9263	3791	3611	435	89	38822	17190	7927
1992	15484	17339	7535	2008	807	43	43216	27731	10393
1993	11347	10526	6737	3903	519	122	33154	21808	11282
1994	8661	4651	7708	3032	1073	162	25287	16626	11975
1995	9575	7027	3033	1255	241	49	21180	11605	4578
1996	11738	7826	5612	1680	392	35	27283	15545	7719
1997	16267	9565	6062	3239	735	194	36063	19796	10231
1998	22410	13304	7294	3832	1311	216	48367	25957	12653
1999	23699	18324	10016	3473	1509	376	57396	33698	15374
2000	18973	19384	12044	5323	1504	611	57839	38865	19481
2001	29183	15444	12513	4732	1843	875	64589	35406	19962
2002	35262	23698	10166	4135	1572	831	75664	40401	16703
2003	21195	28832	15738	4810	1696	1311	73583	52388	23556
2004	30000	17329	21043	9130	2075	1298	80875	50875	33546

Table 13. Fishing mortality rate for Georges Bank yellowtail from a virtual population analysis using the bootstrap bias adjusted population abundance at the beginning of 2003 from Canadian ADAPT software.

Year	Age Group						
	1	2	3	4	5	6+	3+
1973	0.014	0.267	0.704	0.912	0.912	0.912	0.804
1974	0.049	0.572	0.909	1.178	1.178	1.178	1.063
1975	0.074	1.241	1.323	1.469	1.469	1.469	1.392
1976	0.030	1.071	0.952	1.036	1.036	1.036	0.981
1977	0.024	0.735	1.370	1.048	1.048	1.048	1.295
1978	0.237	0.318	0.971	0.927	0.927	0.927	0.955
1979	0.011	0.387	0.702	0.961	0.961	0.961	0.787
1980	0.016	0.235	0.759	0.717	0.717	0.717	0.752
1981	0.001	0.047	0.657	1.244	1.244	1.244	0.896
1982	0.113	0.495	0.827	1.151	1.151	1.151	0.935
1983	0.143	0.773	1.228	0.716	0.716	0.716	1.120
1984	0.057	0.717	1.521	1.984	1.984	1.984	1.792
1985	0.051	0.807	0.787	1.115	1.115	1.115	0.960
1986	0.027	0.828	0.589	0.968	0.968	0.968	0.702
1987	0.022	0.803	1.365	1.398	1.398	1.398	1.374
1988	0.028	0.624	1.117	1.633	1.633	1.633	1.305
1989	0.024	0.116	0.356	0.809	0.809	0.809	0.456
1990	0.021	0.377	0.920	0.968	0.968	0.968	0.926
1991	0.021	0.006	0.436	1.298	1.298	1.298	0.886
1992	0.186	0.745	0.458	1.153	1.153	1.153	0.649
1993	0.692	0.112	0.598	1.091	1.091	1.091	0.797
1994	0.009	0.227	1.615	2.334	2.334	2.334	1.871
1995	0.002	0.025	0.391	0.964	0.964	0.964	0.584
1996	0.005	0.055	0.350	0.626	0.626	0.626	0.425
1997	0.001	0.071	0.259	0.705	0.705	0.705	0.440
1998	0.001	0.084	0.542	0.732	0.732	0.732	0.622
1999	0.001	0.220	0.432	0.637	0.637	0.637	0.504
2000	0.006	0.238	0.734	0.861	0.861	0.861	0.783
2001	0.008	0.218	0.907	0.902	0.902	0.902	0.905
2002	0.001	0.209	0.548	0.691	0.691	0.691	0.604
2003	0.001	0.115	0.345	0.641	0.641	0.641	0.443

Table 14. Beginning of year weight (kg) at age for Georges Bank yellowtail. Age group 6+ is catch weighted. The 2004 value is the average for 1999-2003.

Year	Age Group					
	1	2	3	4	5	6+
1973	0.054	0.188	0.403	0.493	0.564	0.704
1974	0.063	0.186	0.419	0.530	0.599	0.758
1975	0.066	0.185	0.411	0.525	0.613	0.702
1976	0.059	0.186	0.414	0.558	0.641	0.738
1977	0.064	0.190	0.405	0.586	0.705	0.866
1978	0.055	0.185	0.418	0.599	0.709	0.882
1979	0.058	0.182	0.381	0.575	0.706	0.871
1980	0.054	0.183	0.404	0.549	0.726	0.905
1981	0.057	0.186	0.399	0.545	0.681	0.810
1982	0.069	0.173	0.411	0.564	0.672	0.878
1983	0.106	0.182	0.364	0.542	0.692	0.869
1984	0.108	0.183	0.334	0.469	0.623	0.784
1985	0.128	0.242	0.345	0.495	0.605	0.726
1986	0.131	0.247	0.443	0.574	0.730	0.827
1987	0.066	0.236	0.423	0.600	0.672	0.860
1988	0.054	0.191	0.419	0.599	0.755	0.893
1989	0.058	0.186	0.420	0.634	0.779	1.026
1990	0.061	0.171	0.370	0.559	0.711	0.886
1991	0.058	0.164	0.328	0.437	0.647	0.774
1992	0.059	0.172	0.314	0.438	0.558	0.941
1993	0.063	0.169	0.333	0.433	0.542	0.803
1994	0.116	0.160	0.317	0.421	0.564	0.747
1995	0.112	0.193	0.306	0.402	0.524	0.727
1996	0.091	0.215	0.318	0.455	0.579	0.789
1997	0.106	0.206	0.350	0.460	0.616	0.923
1998	0.130	0.227	0.375	0.471	0.592	0.770
1999	0.157	0.263	0.410	0.537	0.637	0.780
2000	0.149	0.282	0.424	0.556	0.693	0.858
2001	0.051	0.230	0.406	0.541	0.705	0.903
2002	0.112	0.197	0.373	0.537	0.713	0.971
2003	0.148	0.255	0.419	0.559	0.735	1.011
2004	0.123	0.245	0.406	0.546	0.697	0.905

Table 15. Beginning of year biomass (t) for Georges Bank yellowtail from a virtual population analysis using the bootstrap bias adjusted population abundance at the beginning of 2004 from Canadian ADAPT software.

Year	Age Group								
	1	2	3	4	5	6+	1+	2+	3+
1973	1500	4306	11524	8316	3834	2070	31549	30049	25743
1974	3115	4178	6026	6138	3318	1752	24527	21412	17234
1975	4456	7105	4267	2494	1790	1128	21239	16784	9679
1976	1335	9519	3767	1263	573	1078	17535	16200	6681
1977	1003	3420	5808	1685	464	686	13066	12063	8643
1978	2764	2318	2944	1789	585	276	10677	7912	5594
1979	1341	5910	2836	1257	683	417	12444	11103	5193
1980	1175	3427	7298	1661	497	191	14249	13074	9647
1981	3406	3286	4837	3774	824	155	16281	12875	9590
1982	1465	8469	5660	2902	1097	117	19711	18245	9776
1983	609	2832	8915	2675	922	235	16187	15579	12746
1984	920	746	1966	2754	1230	312	7928	7008	6262
1985	1841	1594	563	520	400	76	4995	3153	1559
1986	862	2752	1063	349	206	110	5342	4479	1728
1987	457	1234	1685	654	127	138	4295	3838	2604
1988	1027	1063	803	500	166	45	3605	2577	1515
1989	493	2821	1026	326	104	38	4808	4314	1494
1990	706	1155	4095	783	133	31	6904	6198	5043
1991	1259	1516	1245	1578	282	69	5950	4690	3174
1992	914	2978	2369	880	450	40	7632	6718	3740
1993	709	1783	2244	1688	281	98	6804	6095	4311
1994	1008	744	2443	1277	606	121	6199	5191	4446
1995	1070	1358	927	505	126	36	4022	2952	1594
1996	1069	1682	1782	765	227	28	5553	4484	2802
1997	1720	1971	2119	1491	453	179	7933	6213	4242
1998	2916	3023	2734	1806	776	167	11421	8505	5482
1999	3709	4820	4112	1865	961	293	15760	12051	7231
2000	2827	5461	5103	2962	1042	524	17920	15093	9631
2001	1488	3552	5080	2560	1299	790	14769	13281	9729
2002	3953	4679	3789	2221	1121	807	16569	12616	7937
2003	3131	7345	6599	2690	1247	1325	22337	19206	11861
2004	3698	4252	8553	4987	1446	1174	24110	20411	16159

Table 16. Deterministic projection input assumptions and results for Georges Bank yellowtail for 2005 at $F_{0.1}$ using the bootstrap bias adjusted population abundance at the beginning of 2004.

Year	Age Group 1	2	3	4	5	6+	1+	2+	3+
Beginning of Year Population Numbers (000s)									
2004	20000	18772	22304	9853	2351	1470			
2005	20000	16349	13829	13476	5448	2113			
2006	20000	16358	12515	9330	8592	4821			
Partial Recruitment to the									
	0.004	0.269	0.774	1	1	1			
Fishing Mortality									
2004	0.002	0.106	0.304	0.393	0.393	0.393			
2005	0.001	0.067	0.194	0.250	0.250	0.250			
Weight at beginning of year for population (kg)									
	0.123	0.245	0.406	0.546	0.697	0.905			
Maturity		*Fraction of Z before Spawning*				0.4167			
	0	0.52	0.86	1	1	1			
Beginning of Year Projected Population Biomass (t)									
2004	2460	4599	9055	5380	1639	1330	24463	22003	17404
2005	2460	4005	5615	7358	3797	1912	25147	22687	18681
2006	2460	4008	5081	5094	5989	4363	26995	24535	20527
Spawning Stock Biomass (t)									
2004	0	3068	7432	4880	1456	1154	17991		
2005	0	2715	4825	7083	3581	1760	19964		
Projected Catch Numbers									
2004	28	1708	5324	2919	696	435			
2005	18	965	2212	2713	1097	425			
Average weight for catch (kg)									
	0.173	0.357	0.478	0.634	0.793	1.005			
Projected Yield (t)									
2004	5	610	2545	1850	552	438	6000		
2005	3	344	1057	1720	870	427	4422		

Table 17. Fishing mortality rate in 2004, yield in 2005 (t), and change in yield from 2004 to 2005 for a range of models and assumptions regarding partial recruitment in the deterministic projections.

Parameter	Source or Value	Yield 2004	F 2004	Yield 2005	Change in Yield
Init Pop	AdaptBase	5000	0.318	4646	-354
Recruitment	20,000	6000	0.393	4422	-1578
PR	Flat-topped	7000	0.472	4199	-2801
F2005	0.25	8000	0.556	3976	-4024
		9000	0.647	3754	-5246
		10000	0.744	3533	-6467
Init Pop	Asap Flat then Dome	5000	0.195	7108	2108
Recruitment	20,000	6000	0.238	6888	888
PR	Flat-topped	7000	0.282	6669	-331
F2005	0.25	8000	0.329	6451	-1549
		9000	0.377	6232	-2768
		10000	0.427	6014	-3986
Init Pop	Asap Flat then Dome	5000	0.247	5671	671
Recruitment	20,000	6000	0.302	5489	-511
PR	Domed	7000	0.359	5308	-1692
F2005	0.25	8000	0.419	5127	-2873
		9000	0.481	4946	-4054
		10000	0.546	4766	-5234
Init Pop	Asap Dome2Block	5000	0.131	10061	5061
Recruitment	20,000	6000	0.159	9847	3847
PR	Flat-topped	7000	0.187	9634	2634
F2005	0.25	8000	0.217	9420	1420
		9000	0.247	9207	207
		10000	0.278	8994	-1006
Init Pop	Asap Dome2block	5000	0.197	6419	1419
Recruitment	20,000	6000	0.240	6258	258
PR	Domed	7000	0.285	6098	-902
F2005	0.25	8000	0.331	5937	-2063
		9000	0.378	5778	-3222
		10000	0.427	5618	-4382

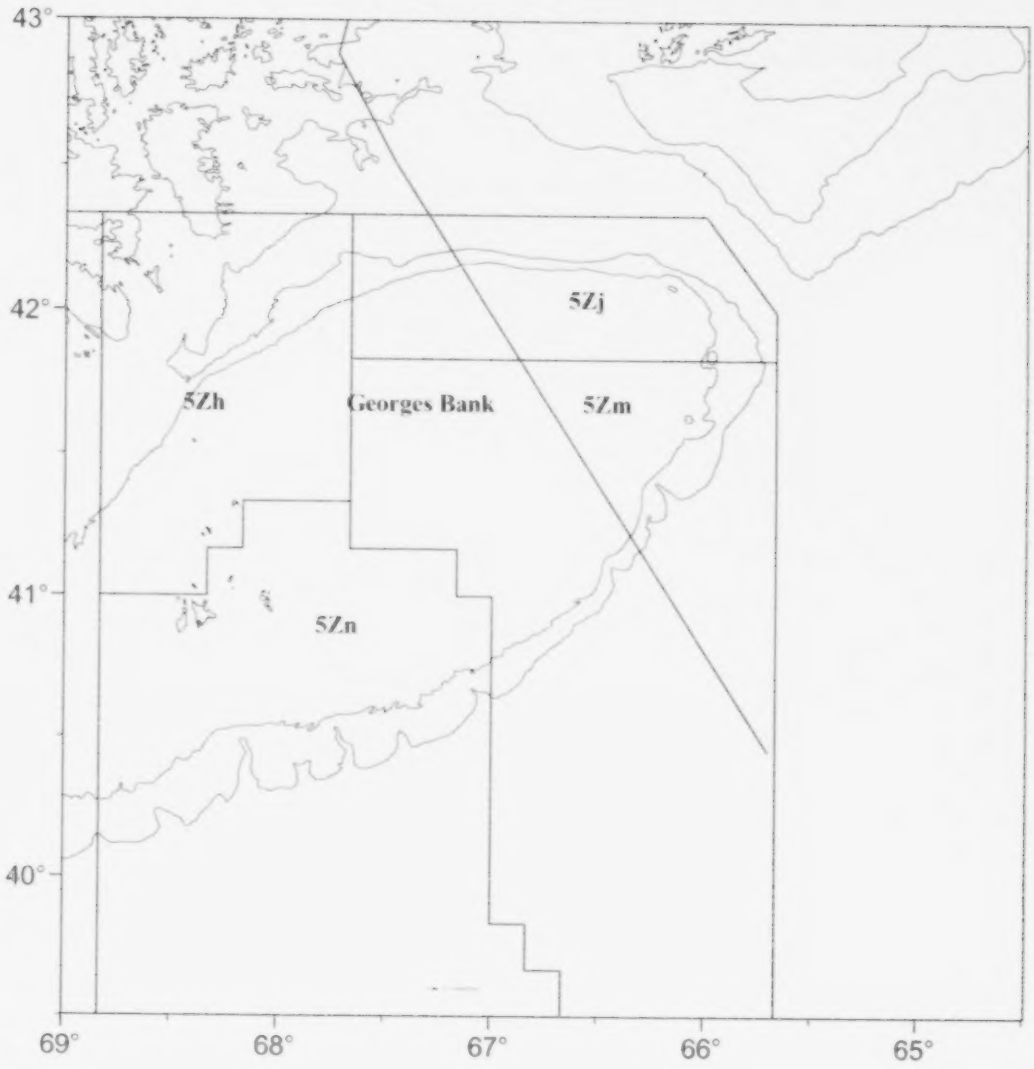


Figure 1a. Location of Canadian fisheries statistical unit areas in NAFO Subdivision 5Ze.

Figure 1b. Statistical areas used for monitoring northeast U.S. fisheries. Catches from areas 522, 525, 551, 552, 561 and 562 are included in the Georges Bank yellowtail flounder assessment. Shaded areas have been closed to fishing year-round since 1994, with exceptions.

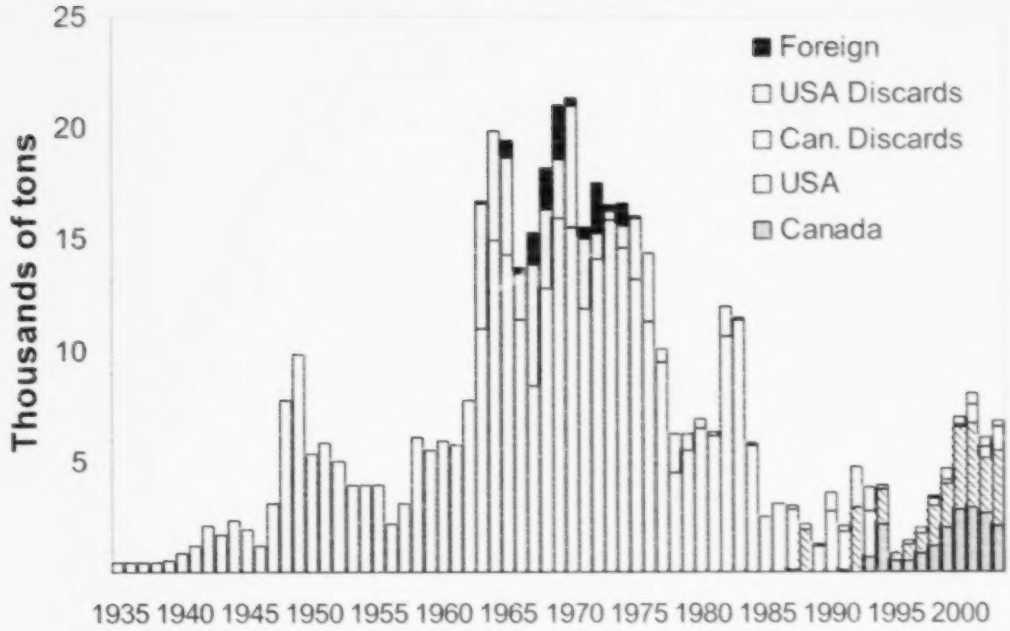


Figure 2. Landings (including discards) of Georges Bank yellowtail flounder by nation, 1935-2003. (Note: Yellowtail flounder discards from the Canadian offshore scallop fishery from 1996-2003 are shown in white and discards from the USA scallop/bottom trawl fisheries for 1963-2003 are shown in light grey).

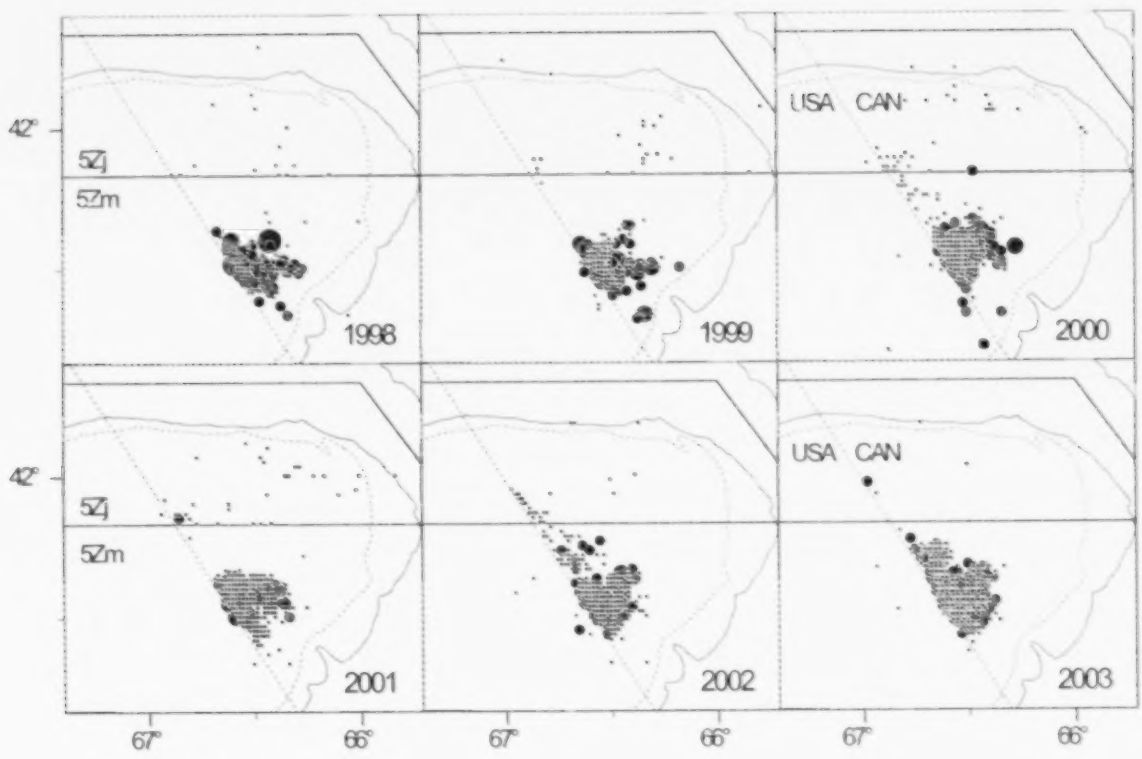


Figure 3. Distribution of Canadian mobile gear (TC 1-3) yellowtail flounder catches from commercial landings data for 1998-2003 where trip landings were greater than 0.5t. Expanding symbols represent metric tonnes.

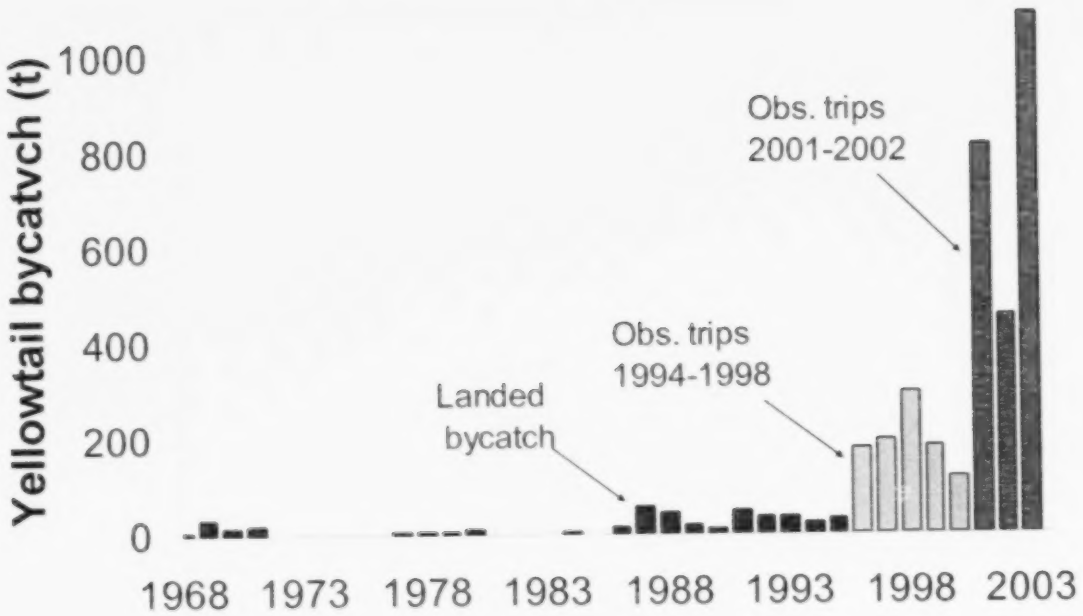


Figure 4. Estimated bycatch of yellowtail flounder from the Canadian offshore scallop fishery on Georges Bank, 1968-2003. Values for 1968-1995 are the actual landed catch of yellowtail by the offshore scallop fleet. Estimates for 1996-2000 are based on bycatch ratios from observed offshore scallop trips in 1994, 1995 and 1998. Estimates for 2001-2003 are based on bycatch ratios from observed offshore scallop trips in 2001 and 2002.

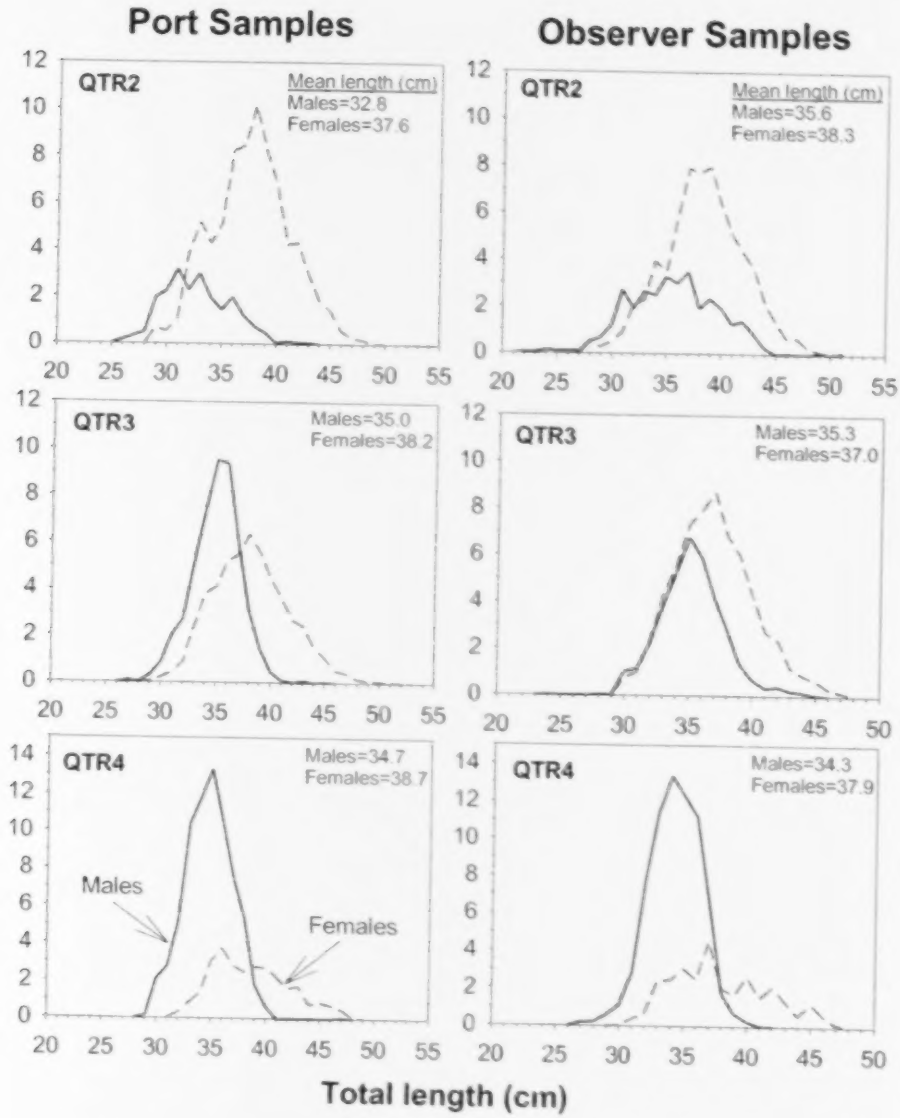


Figure 5. Length frequencies of Georges Bank yellowtail flounder caught in the 2003 Canadian fishery sampled by sex at dockside (left panels) and at sea (right panels) during the same quarter.

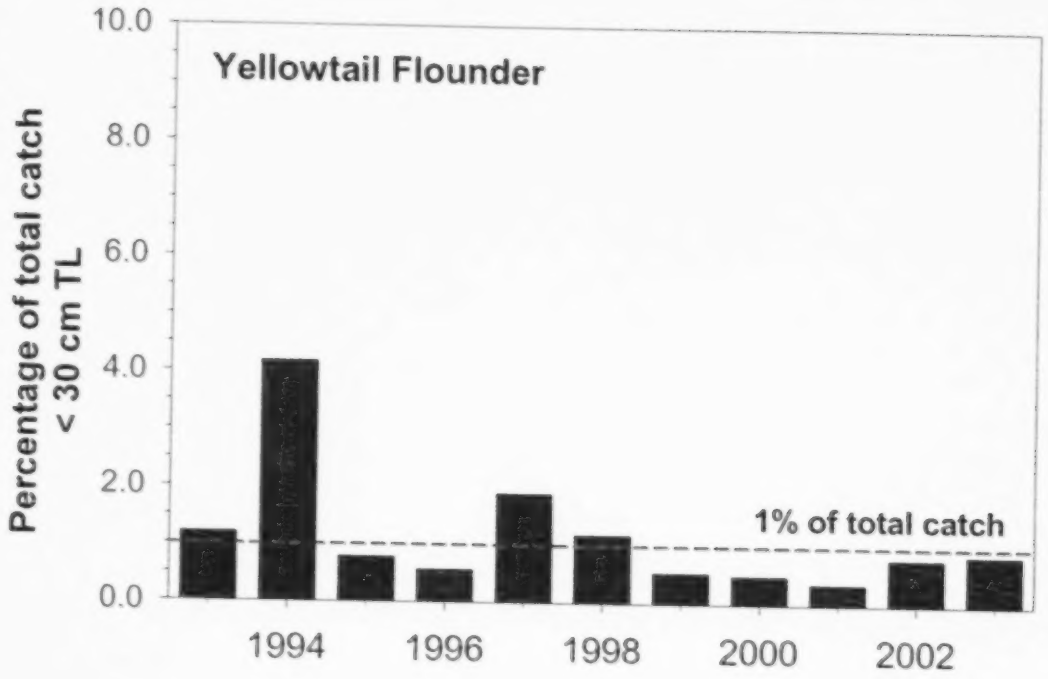


Figure 6. Percentage of total catch of Georges Bank yellowtail flounder less than 30 cm total length from the Canadian fishery, 1993-2003.

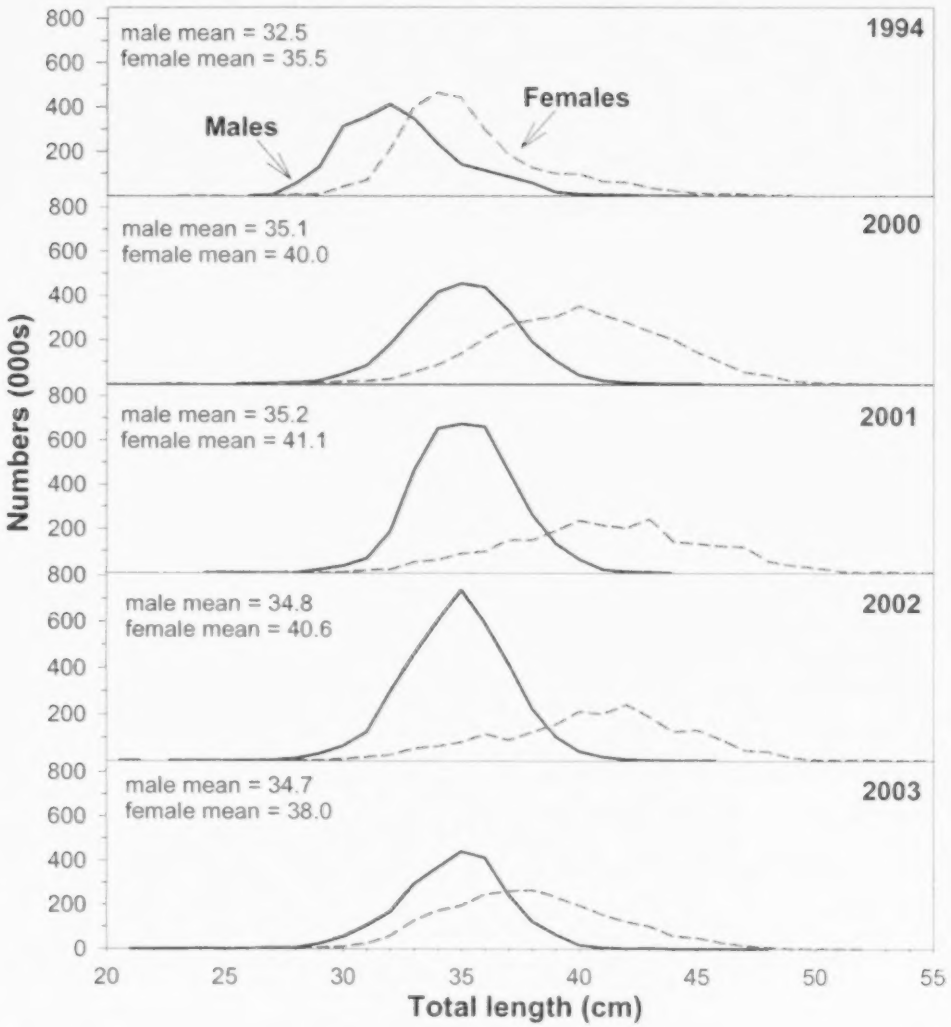


Figure 7. Georges Bank yellowtail flounder length frequency composition by sex for the Canadian fishery in 1994 (beginning of exploitation period) and from 2000-2003.

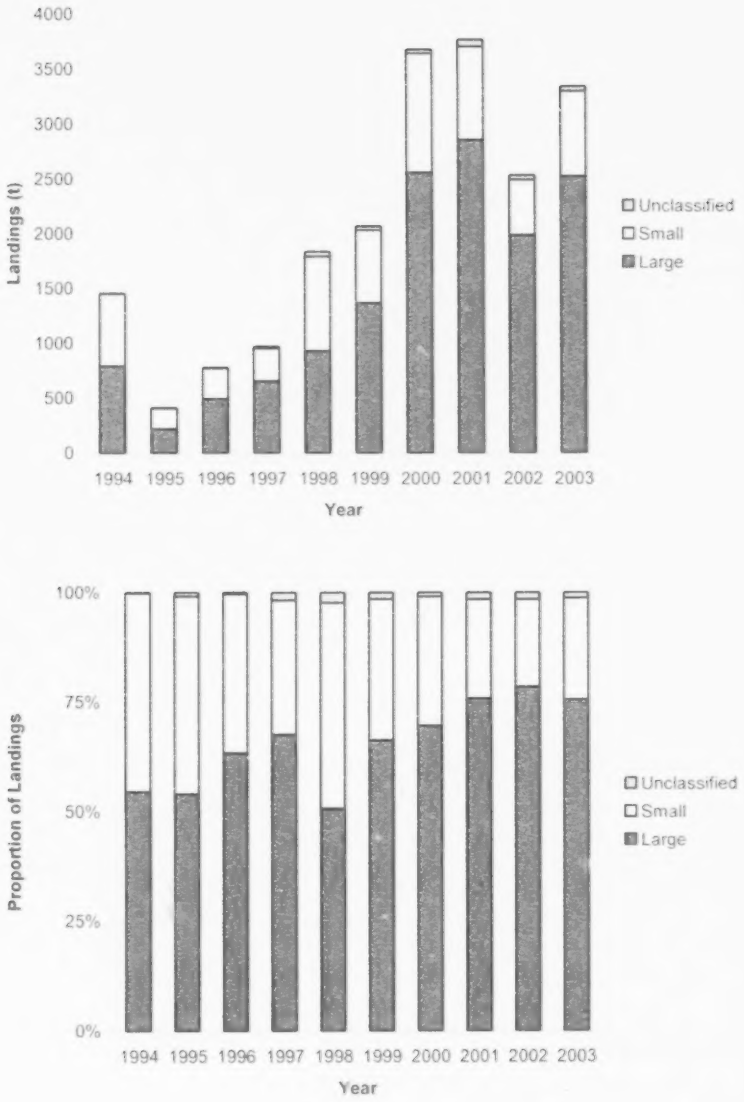


Figure 8. US landings of yellowtail by market category (top panel) and corresponding proportion of landings by market category (bottom panel).

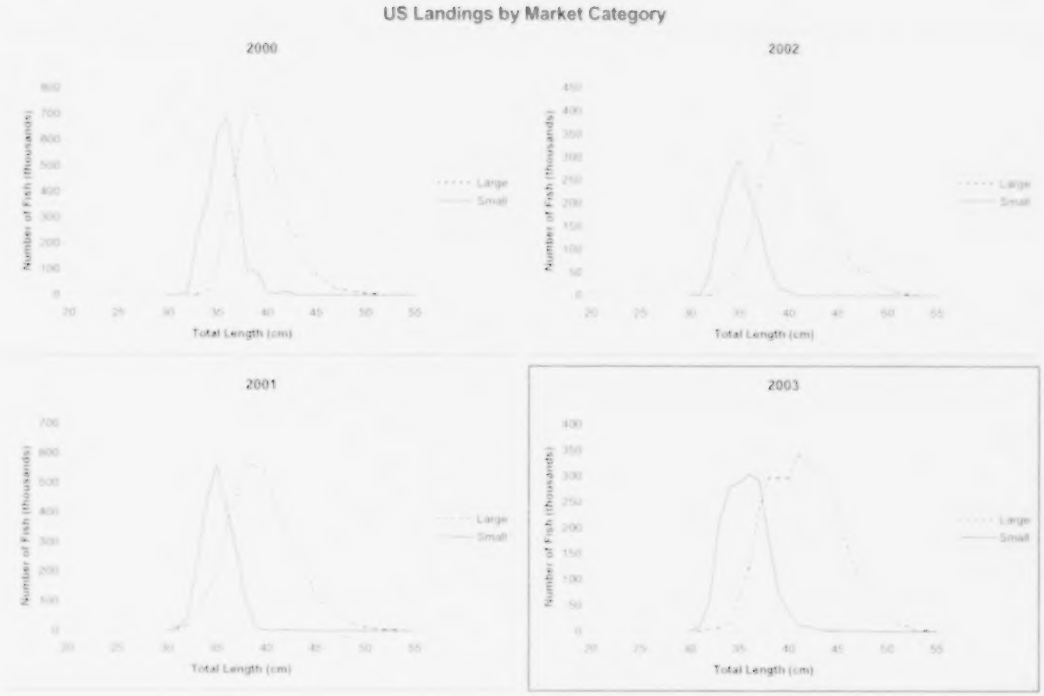


Figure 9. US landings of Georges Bank yellowtail by market category.

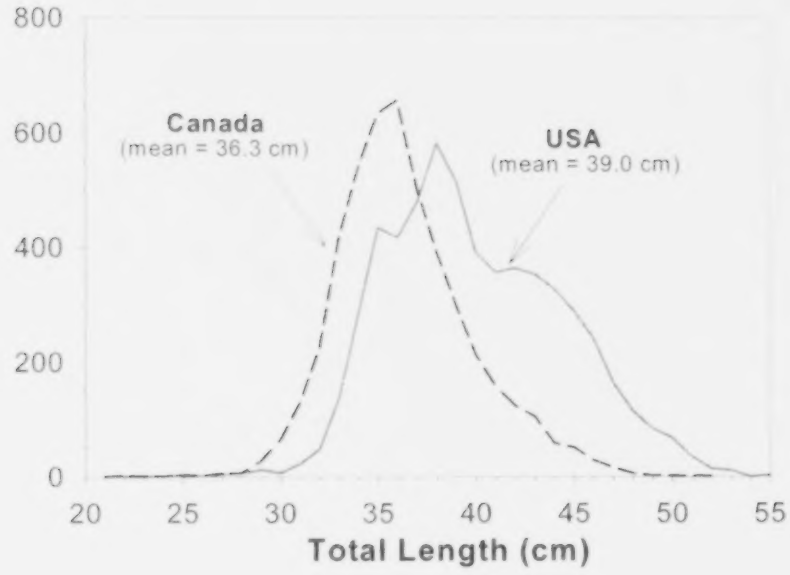


Figure 10. Comparison of Georges Bank yellowtail flounder catch at size from the 2003 Canadian and USA fisheries. The US catch at size also includes discards from the offshore scallop fishery.

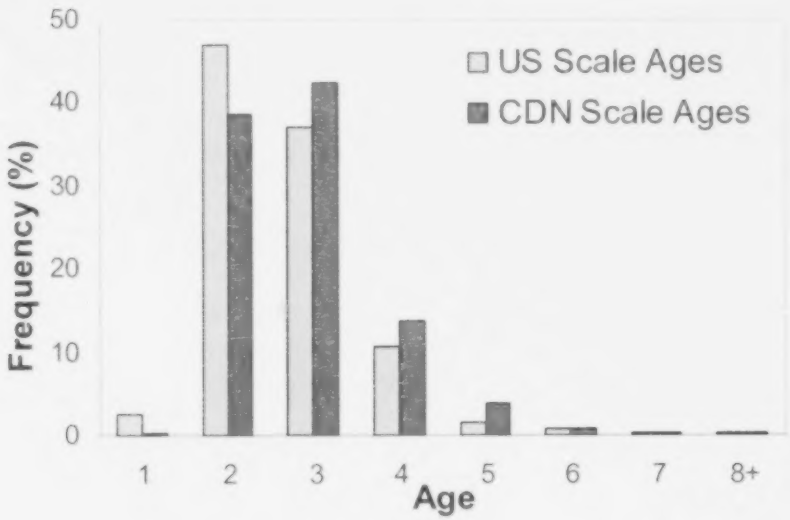


Figure 11. Comparison of the 2003 Canadian commercial fishery catch at age for GB yellowtail flounder using ALK's from US commercial fishery (2nd half) plus NMFS fall survey ages (*n*=585), and Canadian fishery scale samples aged by NMFS (*n*=329).

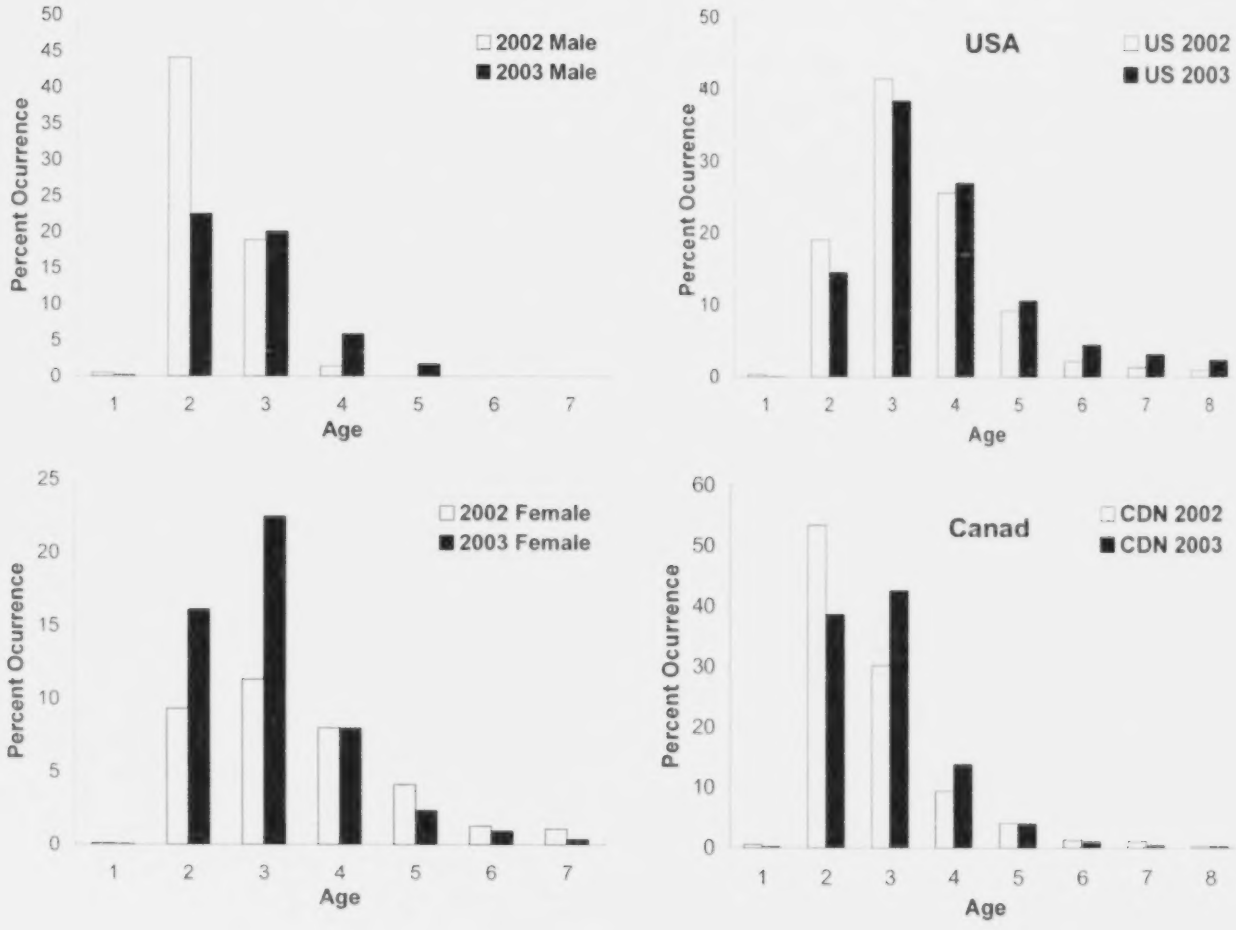


Figure 12. Comparison of 2002 and 2003 Georges Bank yellowtail flounder fishery age composition for Canadian males and females (left panels), USA sexes aggregated (upper right panel) and Canadian sexes aggregated(lower right panel).

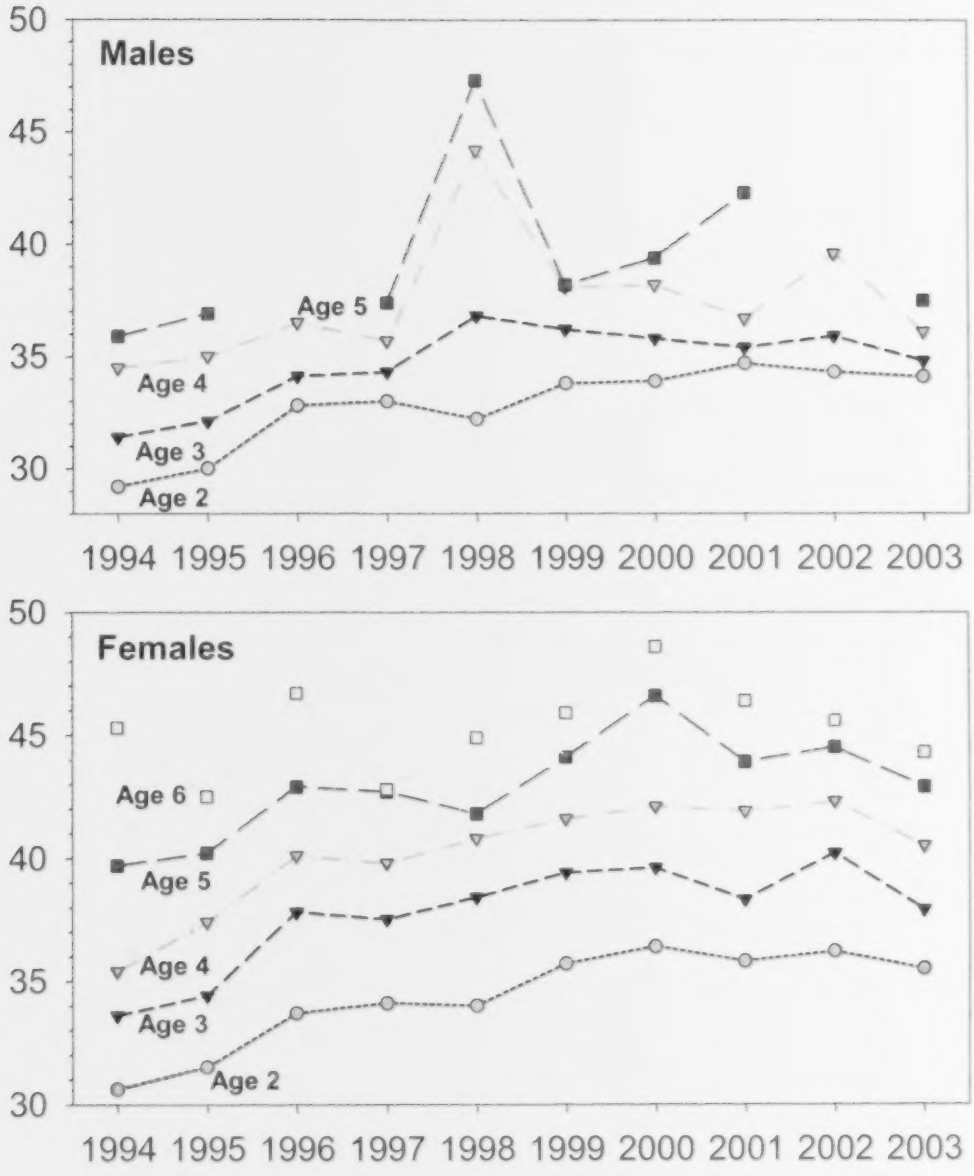


Figure 13. Mean length at age for male (upper panel) and female (lower panel) yellowtail flounder from the Canadian commercial fishery, 1994-2003.

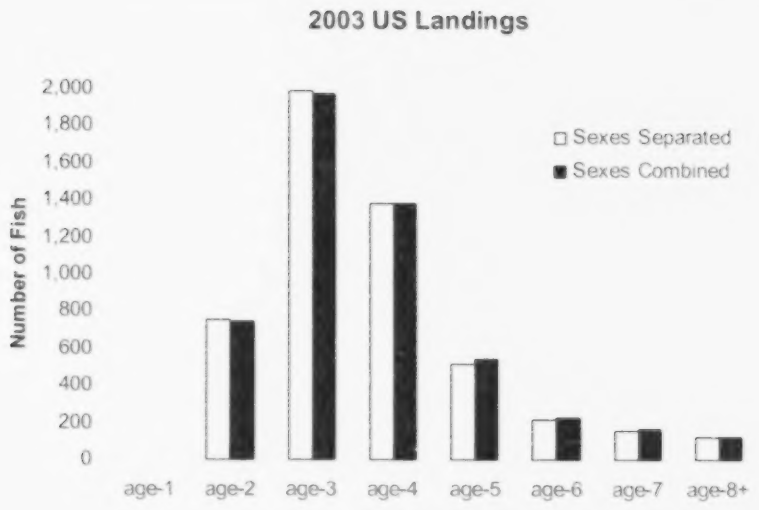


Figure 14. Comparison of US landings at age when sexes are treated separately versus combined.

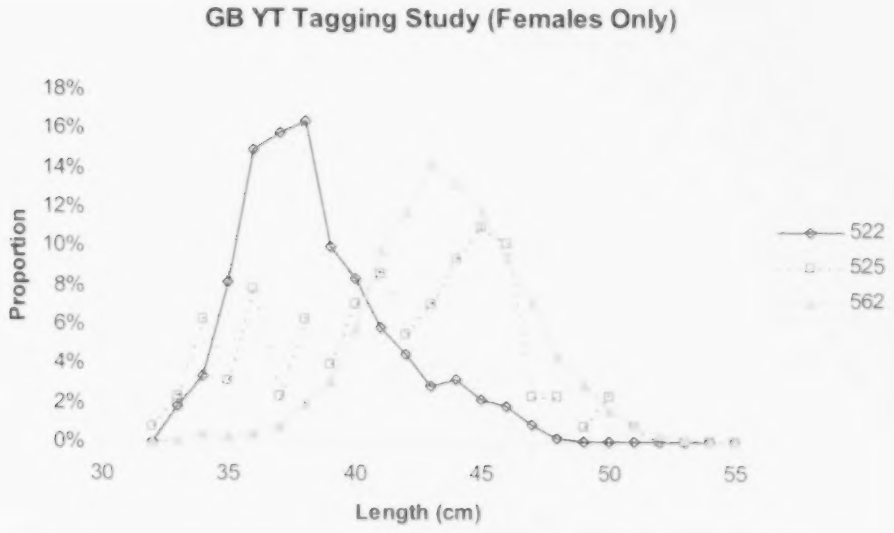


Figure 15. Proportion of female yellowtail at length caught during a tagging study in 2003 on Georges Bank (data kindly provided by S. Cadrin, NMFS).

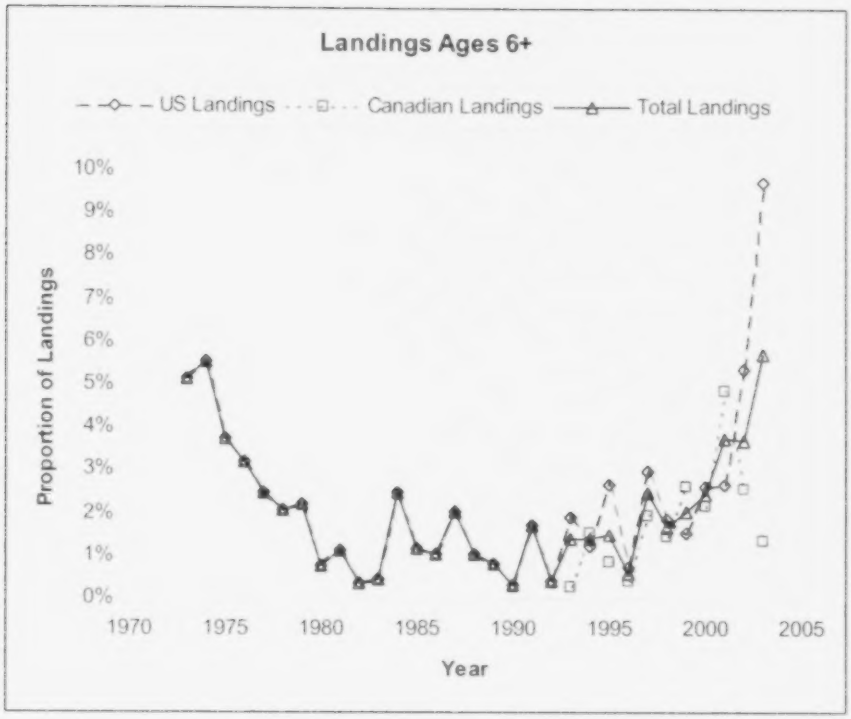


Figure 16. Proportion of landings comprised of ages 6 and older in the US, Canada, and combined.

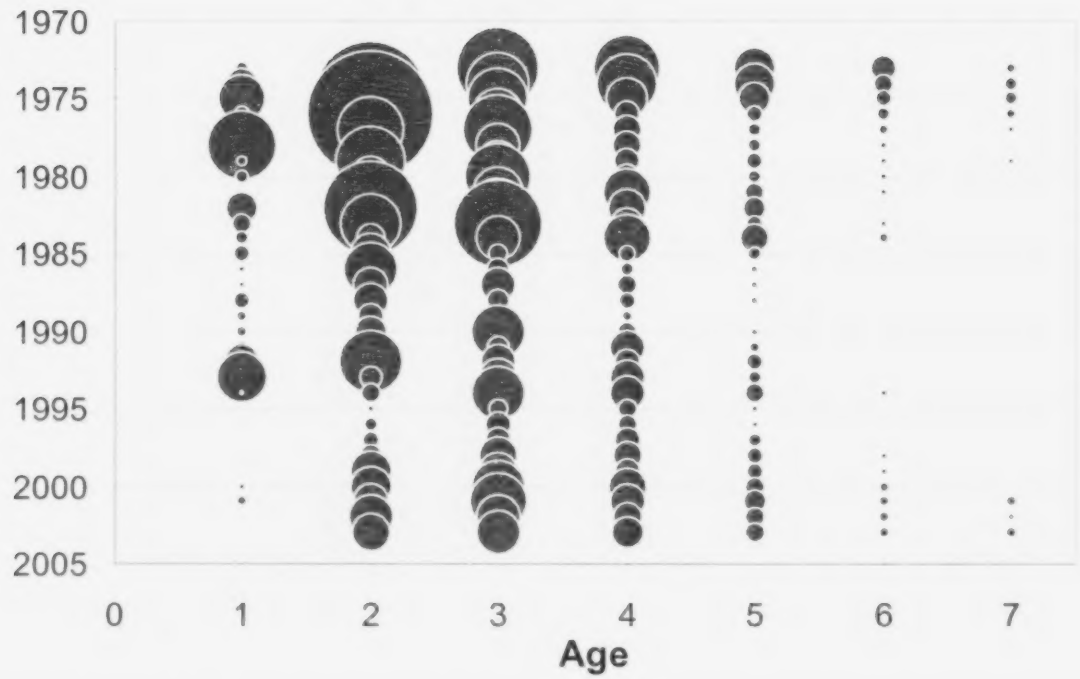


Figure 17. Catch at age for Georges Bank yellowtail flounder, Canadian and USA fisheries combined, 1973-2003. (The area of the bubble is proportional to the magnitude of the catch).

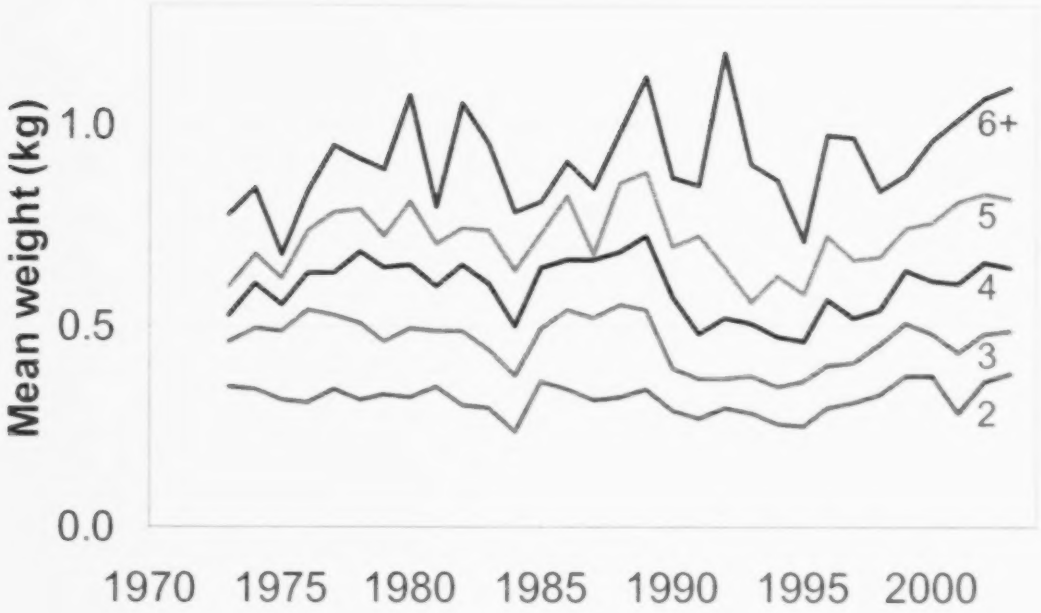


Figure 18. Trends in mean weight at age from the 5Zjhmn yellowtail fishery, 1973 to 2003 (Canada and USA combined including US discards but not Canadian discards).

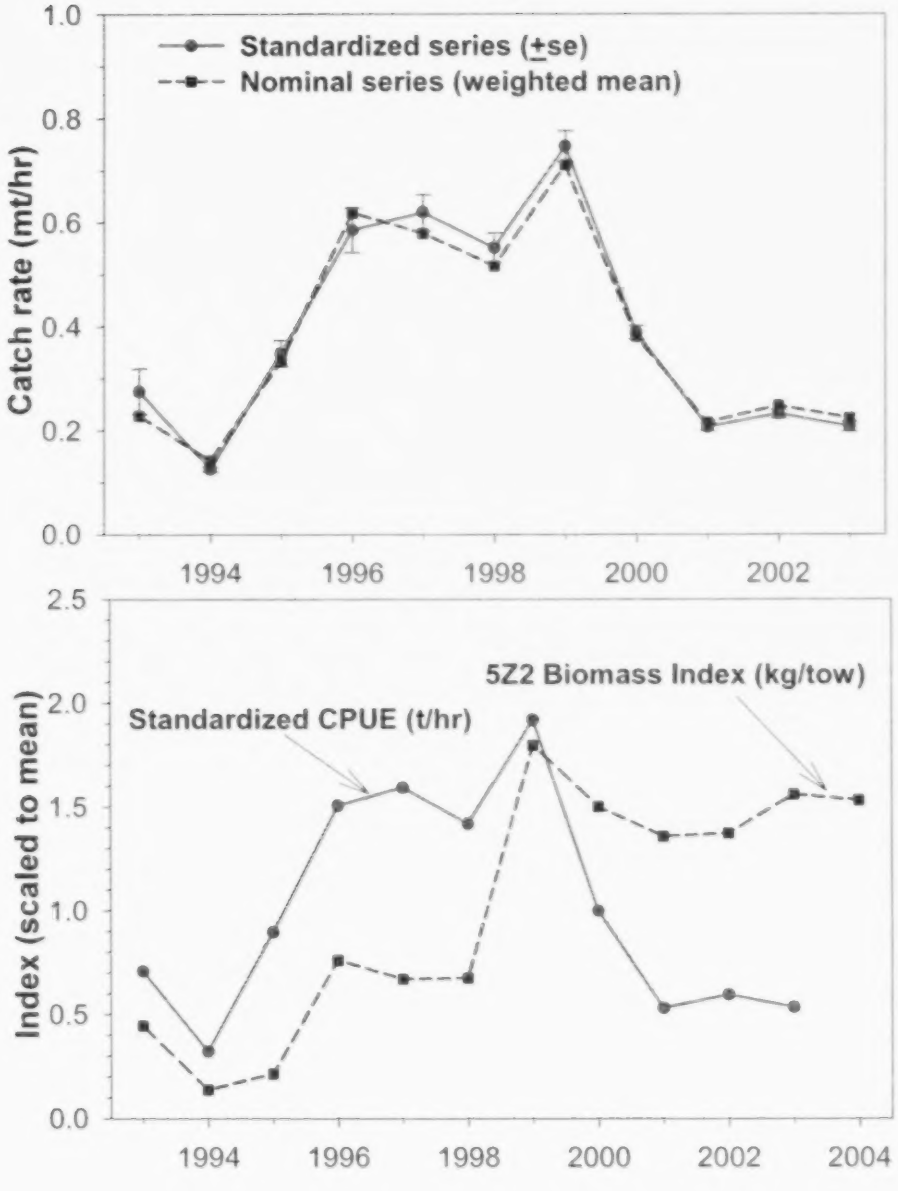


Figure 19. Upper Panel: Nominal and standardized catch rates (tonnes/hour) for Canadian stern trawlers (TC 1-3) fishing for yellowtail flounder on Georges Bank based on directed trips in 5Zm with catches ≥ 2.0 t, 1993-2003. Lower Panel: Standardized CPUE for the Canadian fishery (1993-2003) and DFO spring survey biomass index for stratum 5Z2 (1993-2004).

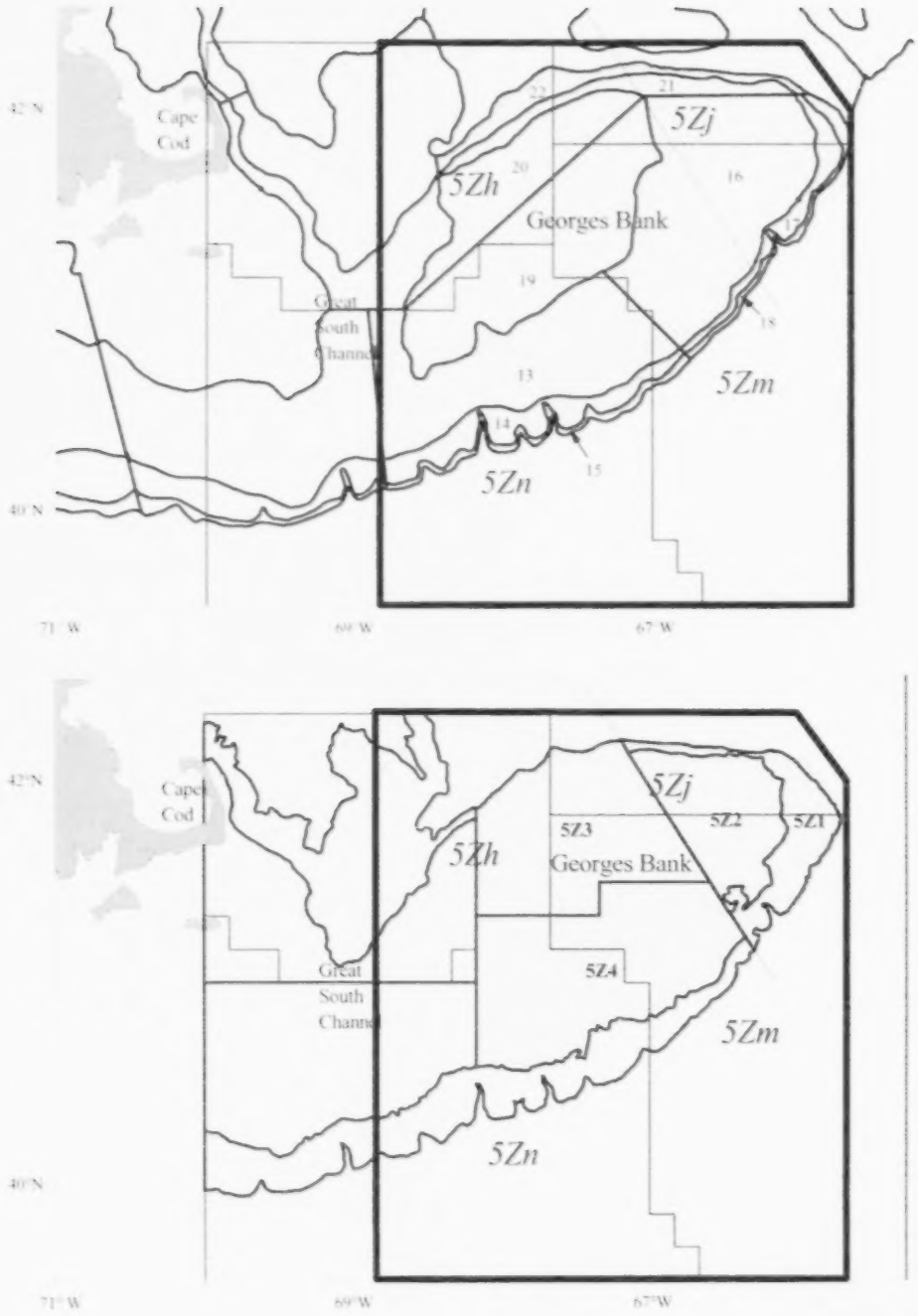


Figure 20. NMFS (top) and DFO (bottom) strata used to derive research survey abundance indices for Georges Bank groundfish surveys. Note NMFS stratum 22 is not used in assessment.

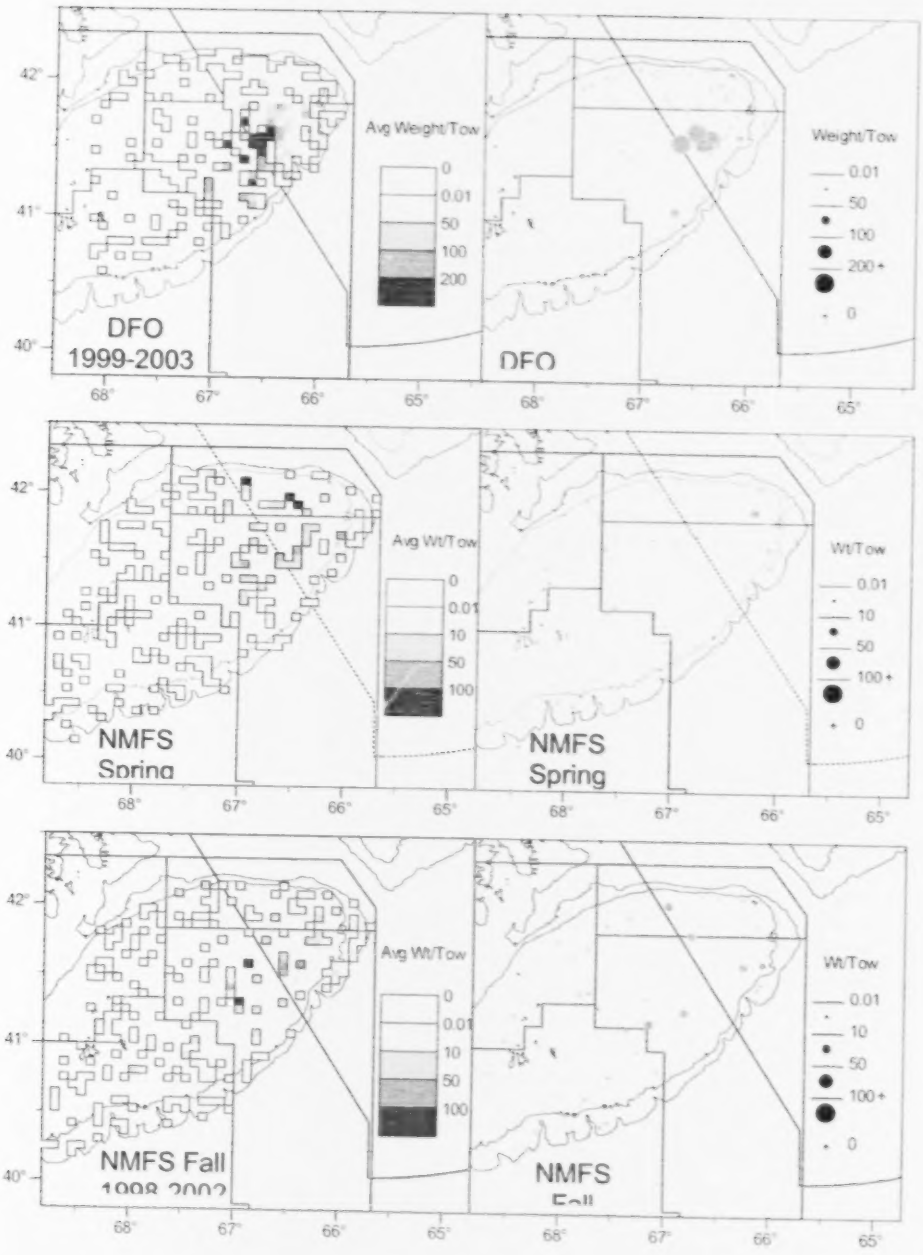


Figure 21. The distribution of catches (kg/tow) of yellowtail flounder (solid circles) in the DFO spring (2004), NMFS spring (2004) and NMFS fall (2003) surveys, respectively, compared with the average distribution in the previous five years (3x5 minute shaded rectangles).

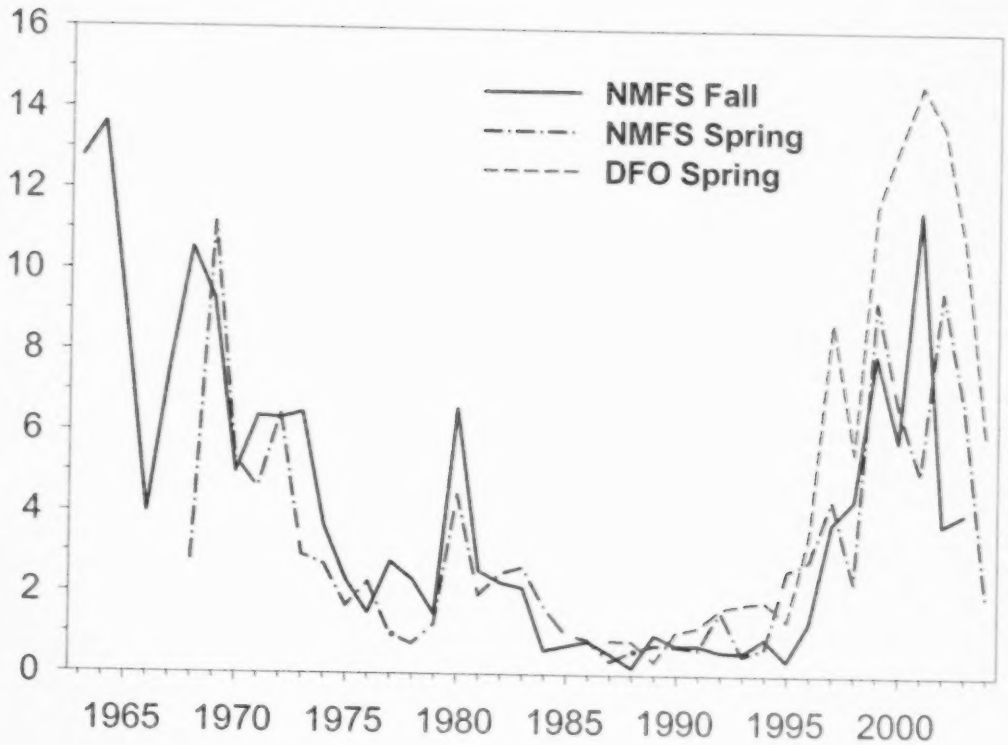


Figure 22. NMFS and DFO spring and NMFS fall survey biomass indices for yellowtail flounder on Georges Bank. The DFO series was also adjusted for catchability differences.

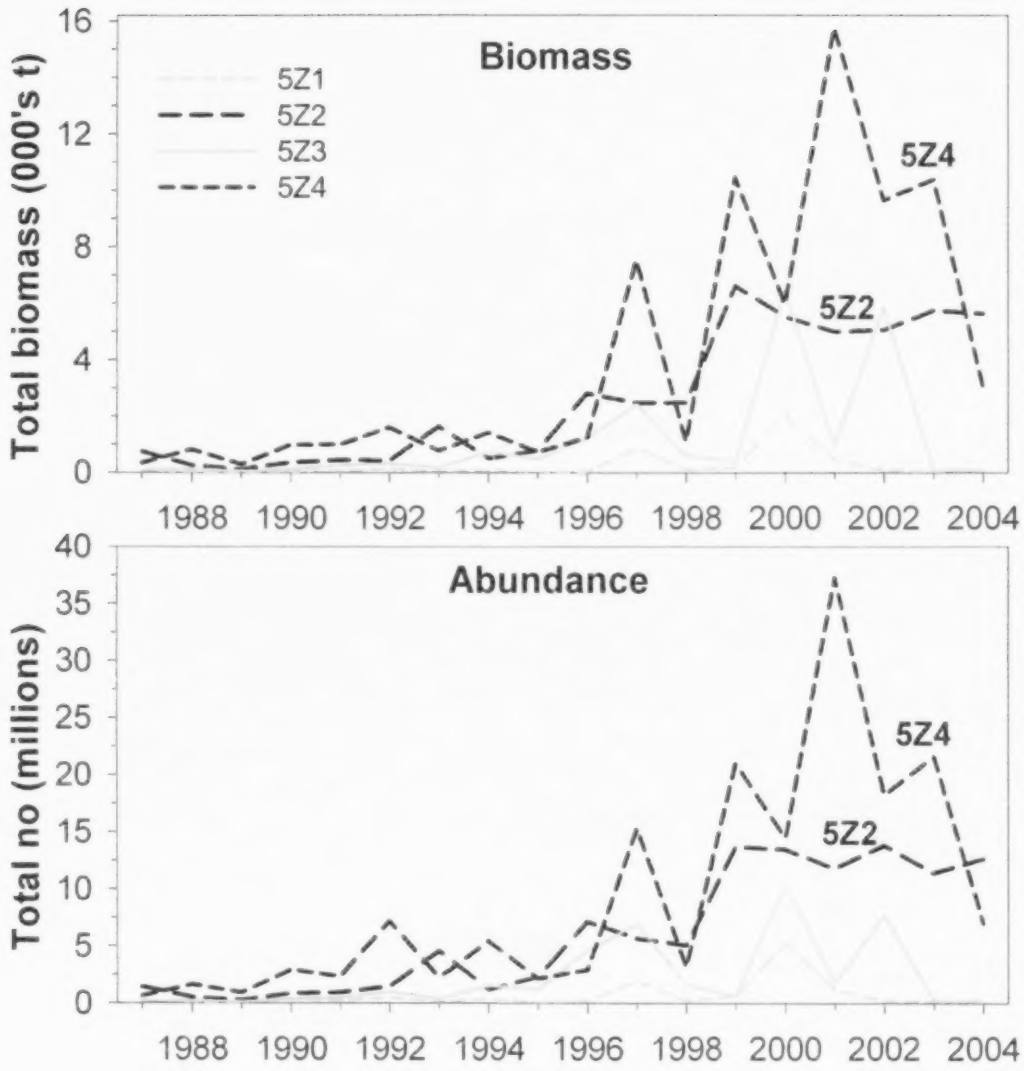


Figure 23. DFO spring survey estimates of total biomass (top panel) and total number (bottom panel) by stratum area for yellowtail flounder on Georges Bank, 1987-2004.

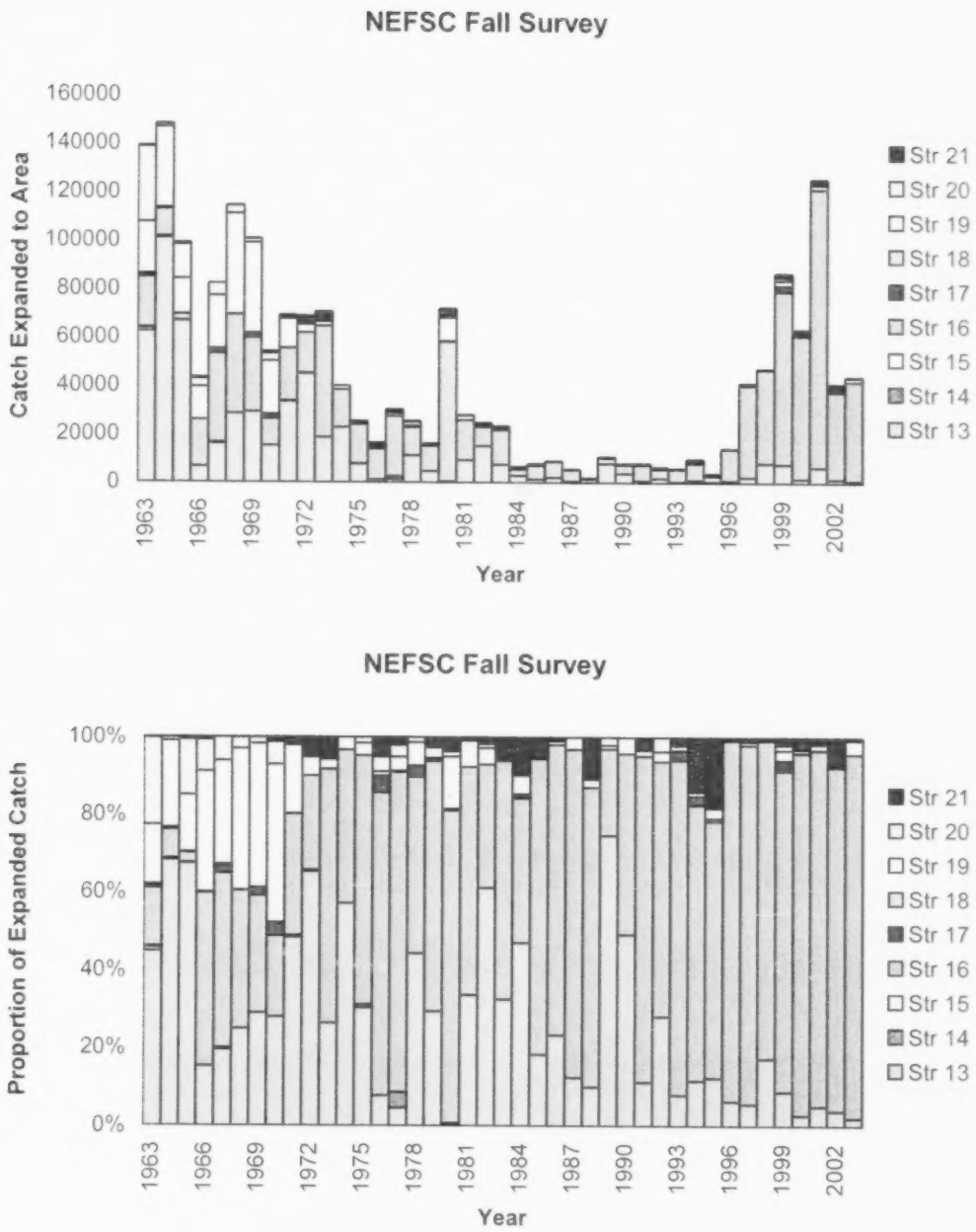


Figure 24. Catch per tow in weight expanded to area for each stratum (top panel) and proportion of expanded catch in each stratum (bottom panel) from the NMFS fall survey.

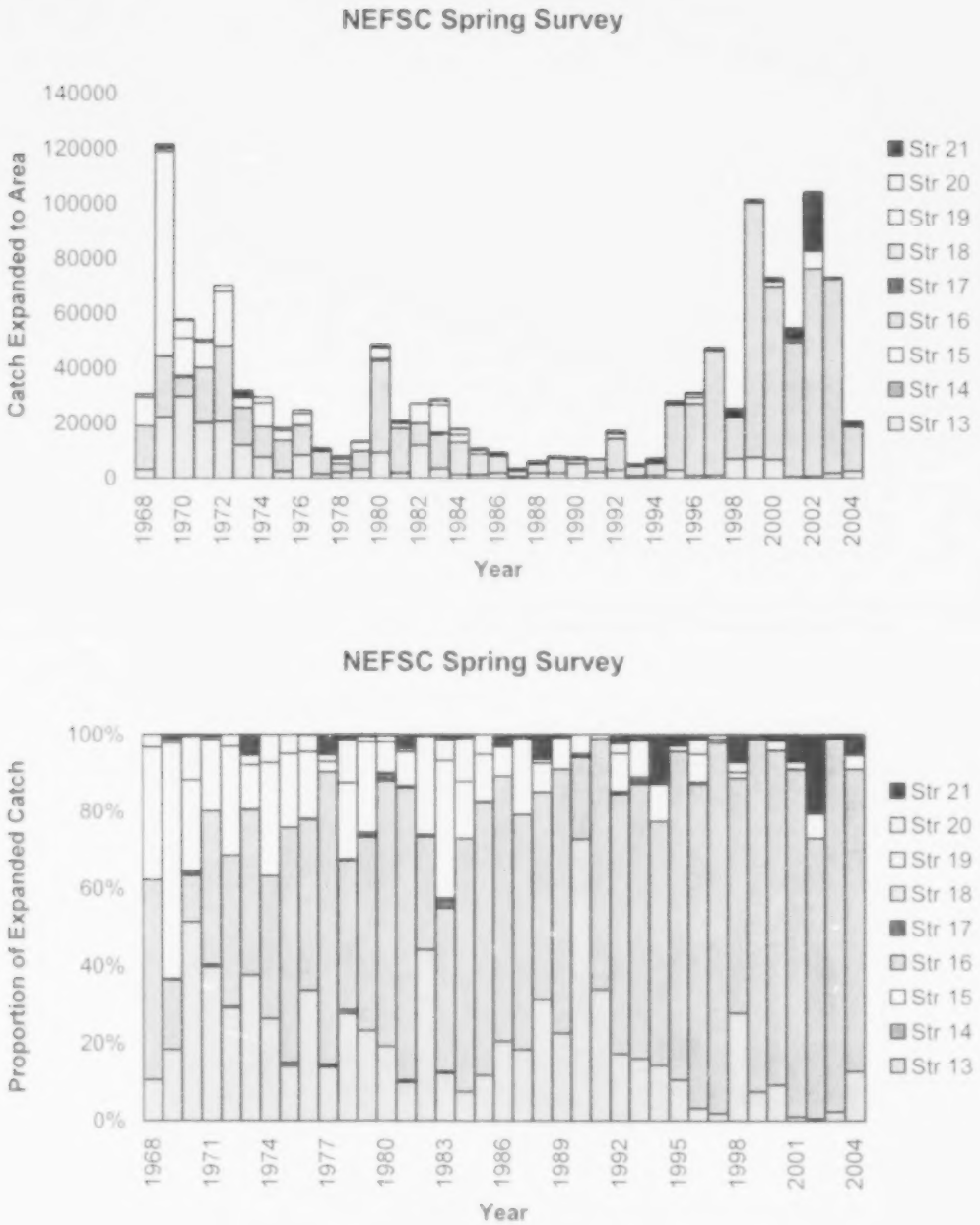


Figure 25. Catch per tow in weight expanded to area for each stratum (top panel) and proportion of expanded catch in each stratum (bottom panel) from the NMFS spring survey.

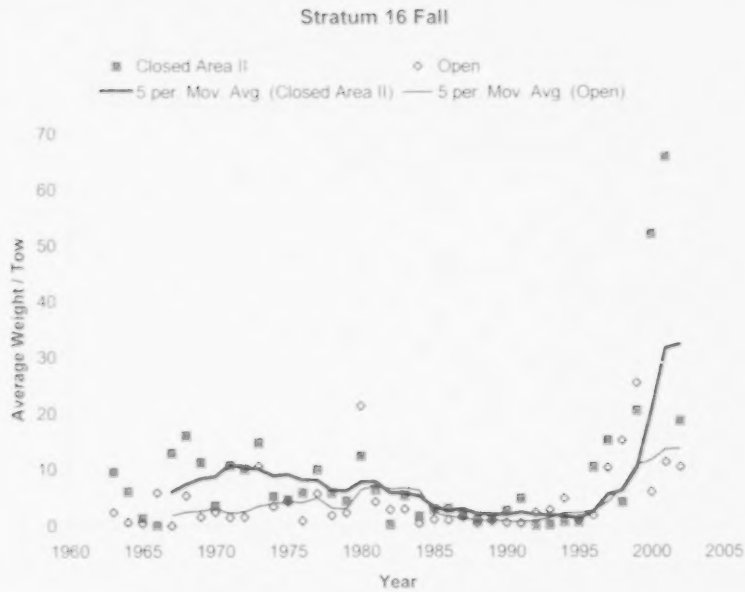


Figure 26. Mean catch per tow in weight from the NMFS fall survey when tow locations were post-stratified as either inside or outside a current closed area boundary.

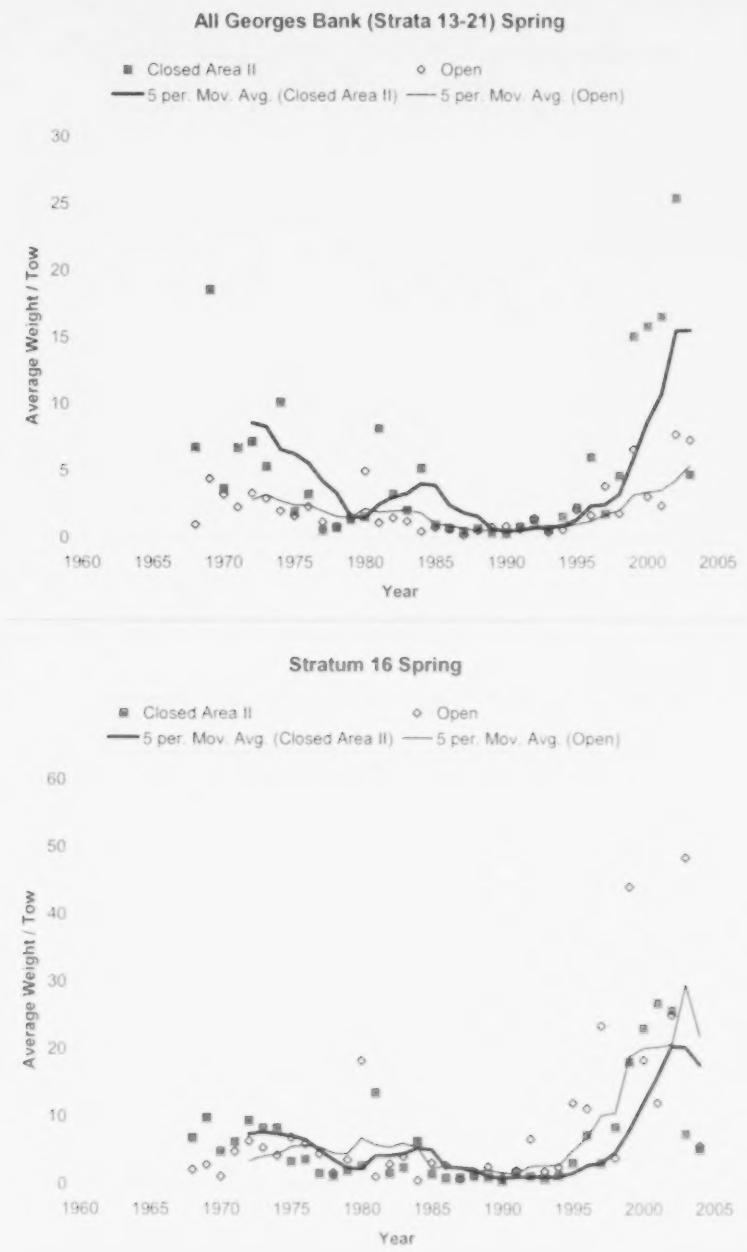
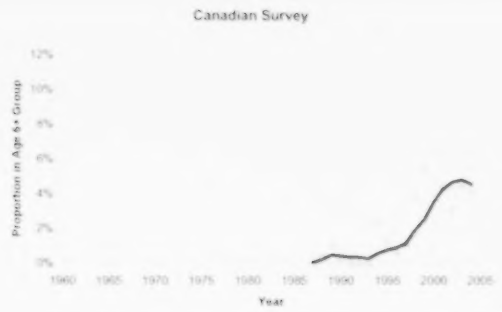


Figure 27. Mean catch per tow in weight from the NMFS spring survey when tow locations were post-stratified as either inside or outside a current closed area boundary.

Figure 28. Standardized survey values, $\ln(y_{s,a})$-mean($\ln(y_{s,a})$), where "y" is catch per tow in numbers, "s" denotes survey and "a" denotes age, for the DFO (Canada), NMFS fall USfall), NMFS spring (USspr), and NMFS scallop (USs2) surveys.



Simple Equilibrium Calculations

Z =	0.2	0.3	0.45	0.6	0.9
Age			Number at Age		
1	1	1	1	1	1
2	0.819	0.741	0.638	0.549	0.407
3	0.670	0.549	0.407	0.301	0.165
4	0.549	0.407	0.259	0.165	0.067
5	0.449	0.301	0.165	0.091	0.027
6+	2.029	0.861	0.291	0.110	0.019
sum 2-6+	4.517	2.858	1.760	1.216	0.685
prop 6+	45%	30%	17%	9%	3%

Figure 29. Proportion of fish ages 6 and older relative to the total number of fish ages 2 and older observed in the NMFS Spring, NMFS Fall, and Canadian surveys. The solid lines are five year moving averages. The simple equilibrium calculations assume full selectivity for all ages.

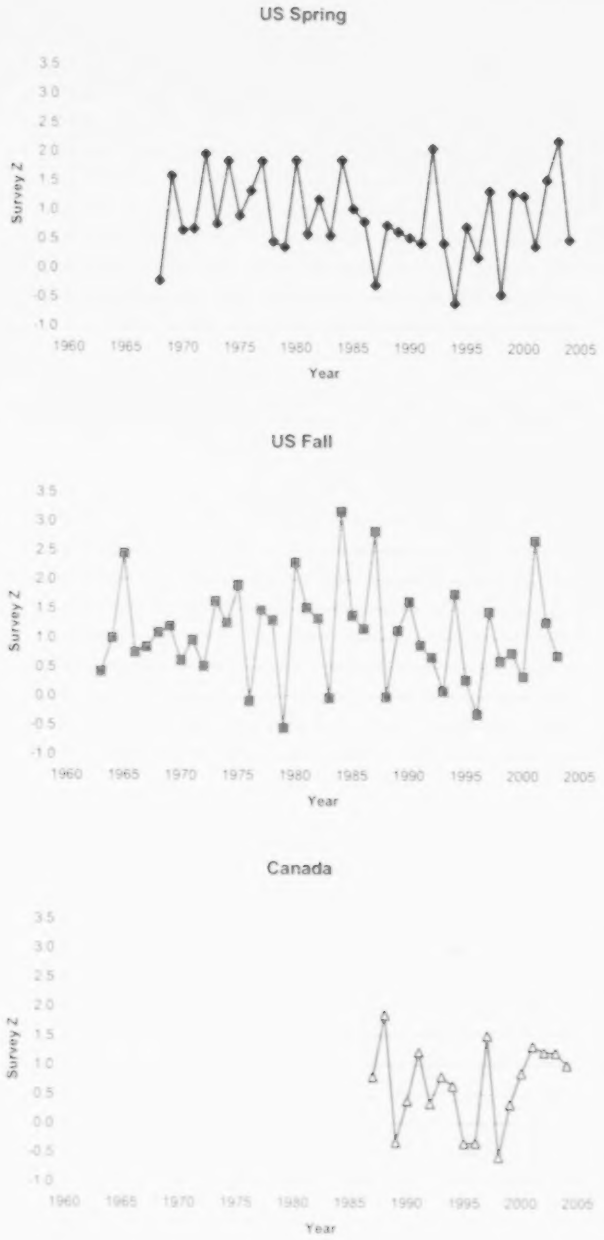


Figure 30. Total mortality estimates computed from the three surveys for Georges Bank yellowtail flounder. The age ranges used for the calculations are NMFS 3-7 and DFO 3-5.

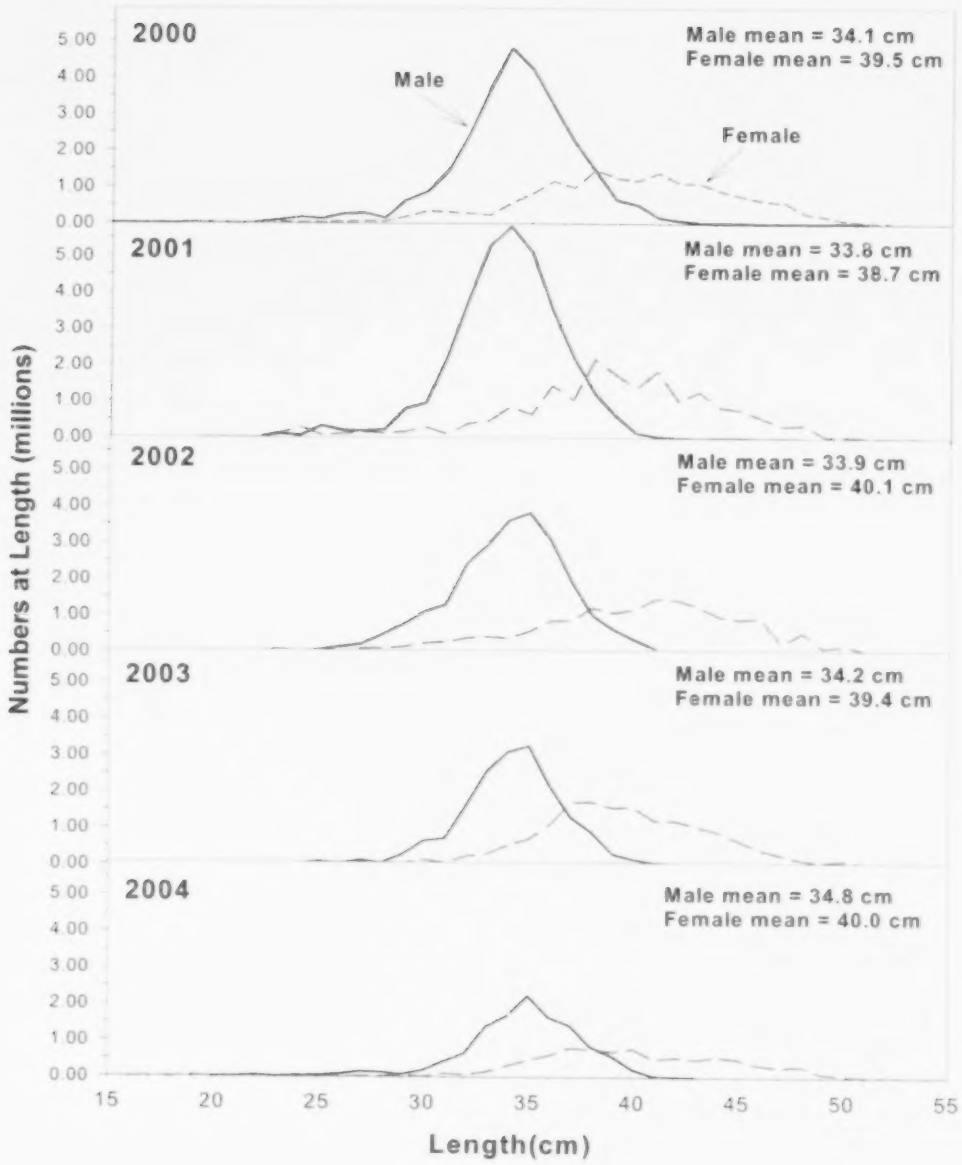


Figure 31a. Comparison of yellowtail flounder length composition in DFO spring surveys on Georges Bank, 2000-2004.

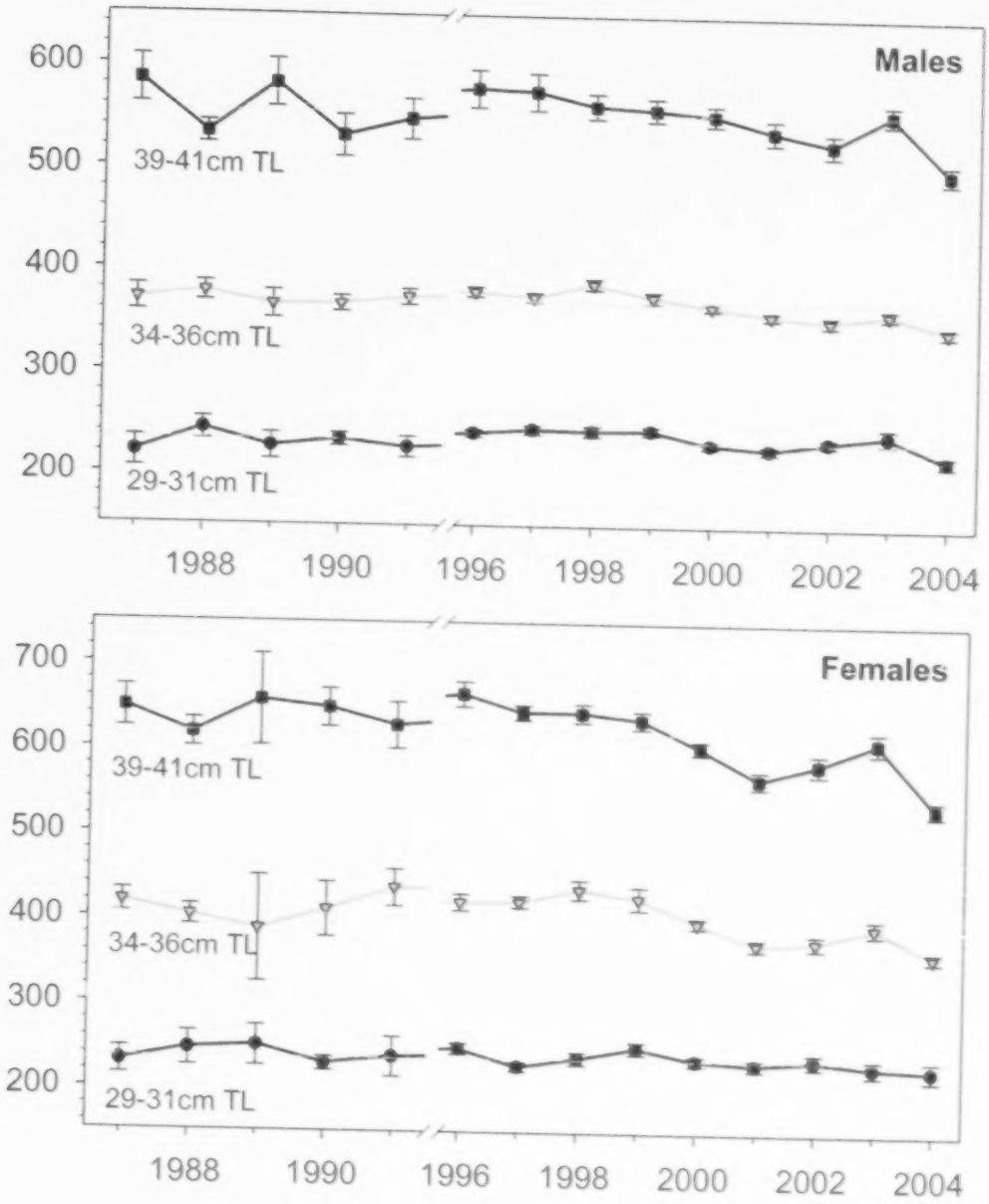


Figure 31b. Trends in mean weight at 29-31cm, 34-36cm and 39-41cm cm TL for male and female yellowtail flounder sampled during February bottom trawl surveys conducted by DFO during 1987-1991 and 1996-2003. The dashed line is the long term mean for each series. Vertical bars represent ± 1SE.

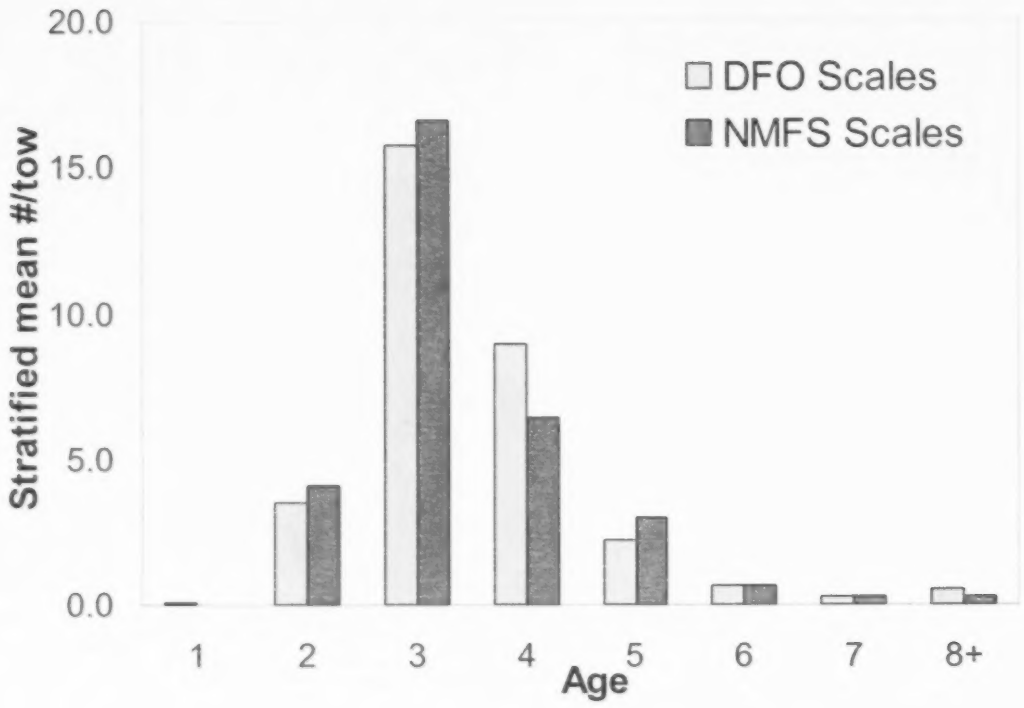


Figure 32. Comparison of 2004 DFO spring survey abundance indices based on ALK's from scales collected during the 2004 survey and aged by the NMFS age reader (n=338) and from scales collected from the 2004 NMFS spring survey applied to DFO survey abundance at length (*n*=96 + 40 for filling in missing ages).

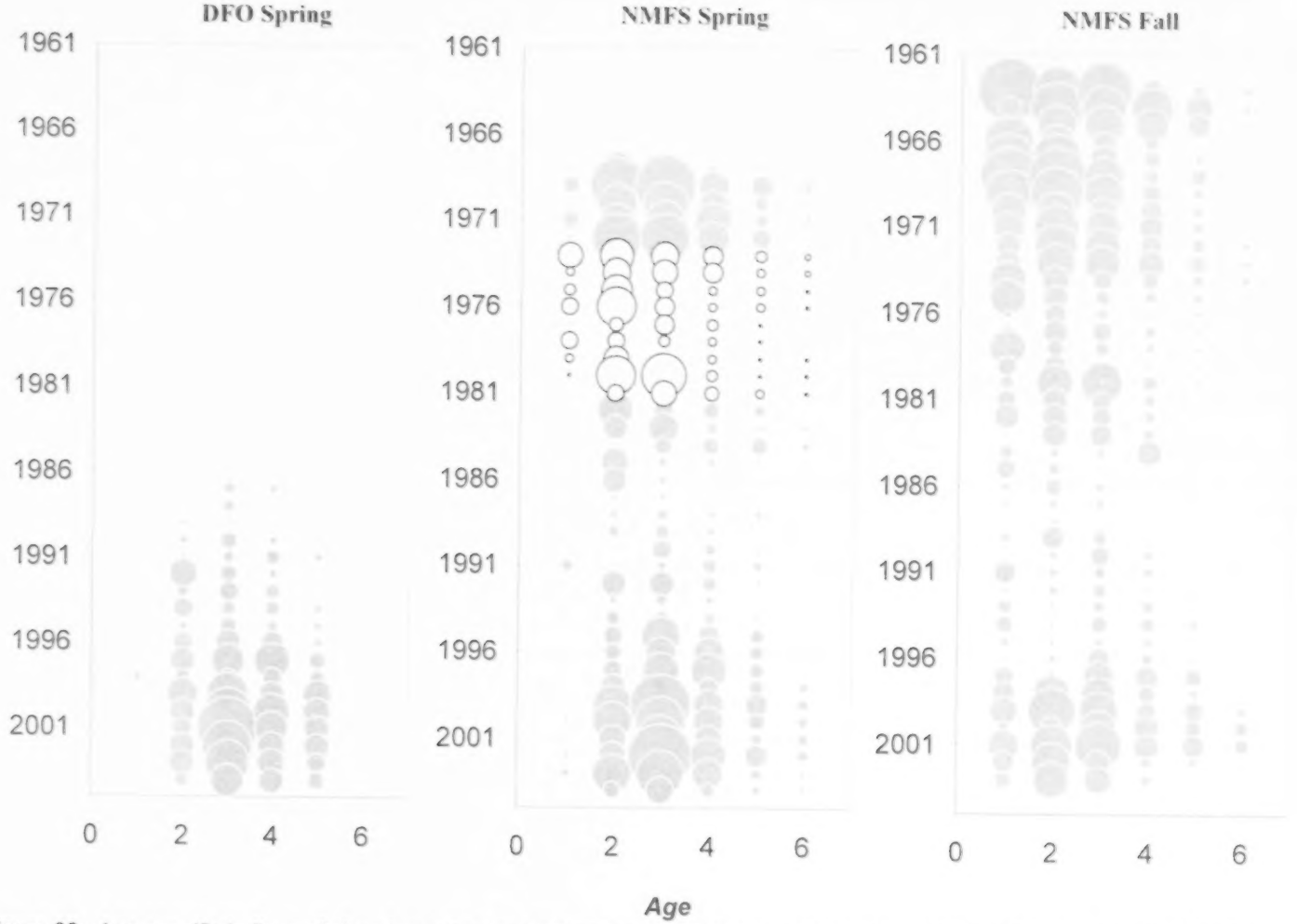


Figure 33. Age specific indices of abundance for the DFO spring (1987-2004), NMFS spring (1968-2004), and NMFS fall (1963-2003) surveys (bubble is proportional to the magnitude). The yellow symbols in the NMFS spring series denote the period when the Yankee 41 net was used. Refer to Tables 8, 9 and 10 for the absolute value of the indices.

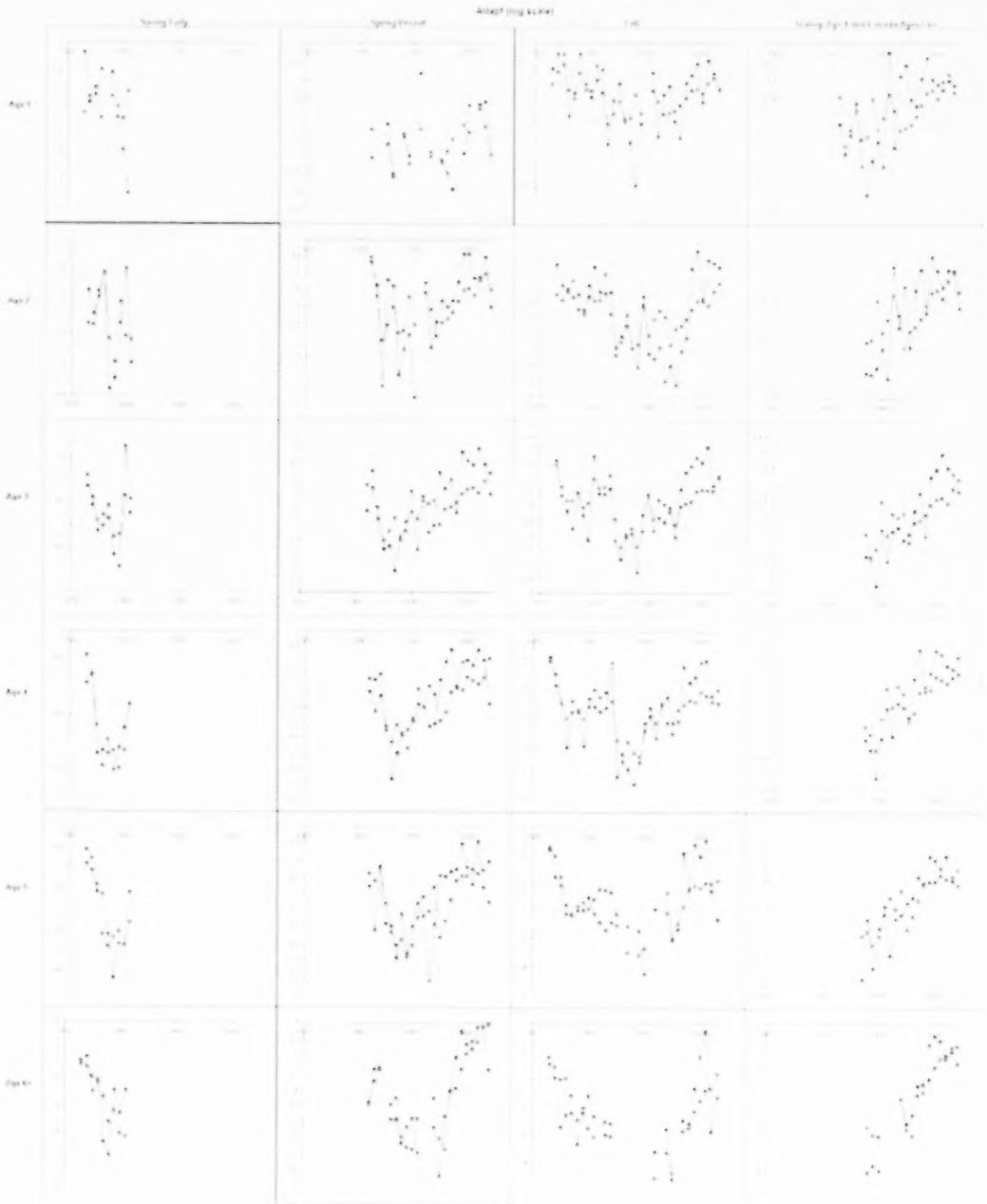


Figure 34. Observed (diamonds) and predicted (squares) indices plotted on log scale axes for the base case VPA, results from NMFS NFT VPA software.

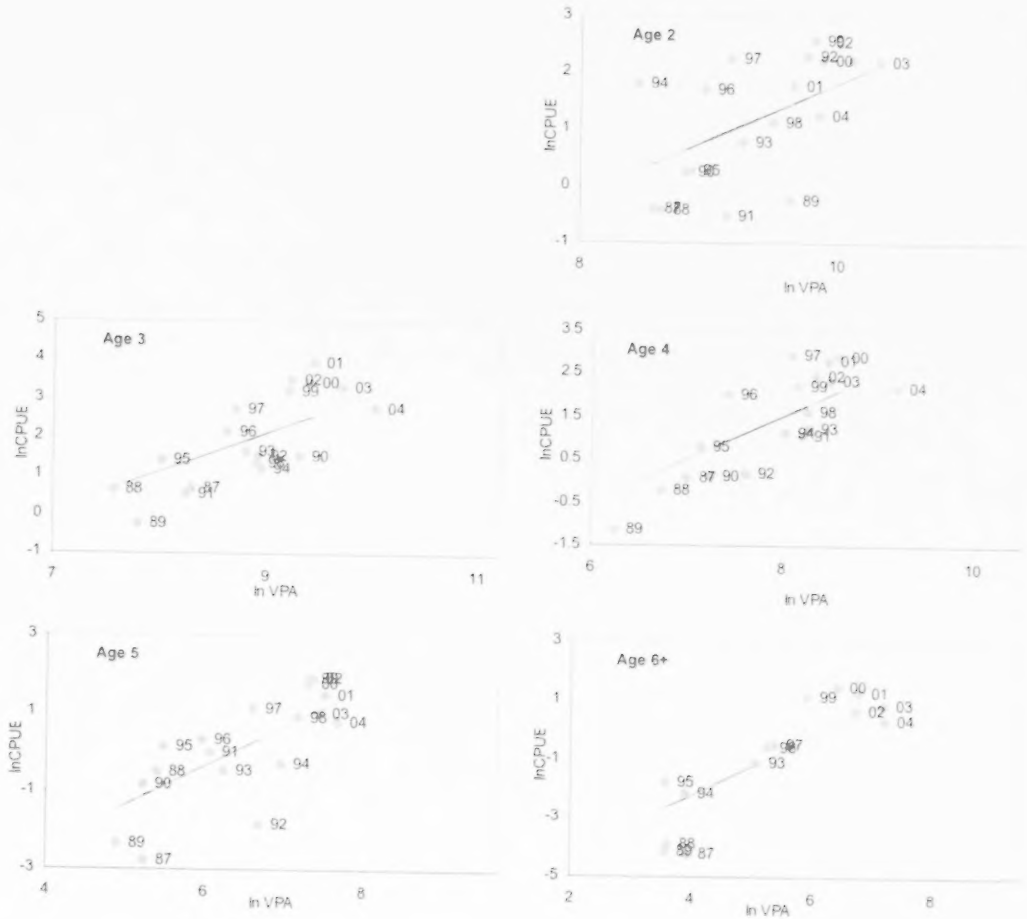


Figure 35. Age by age plots of the observed and predicted ln abundance index vs population numbers for Georges Bank yellowtail flounder from the DFO spring survey 1987-2004 from the Canadian ADAPT results.

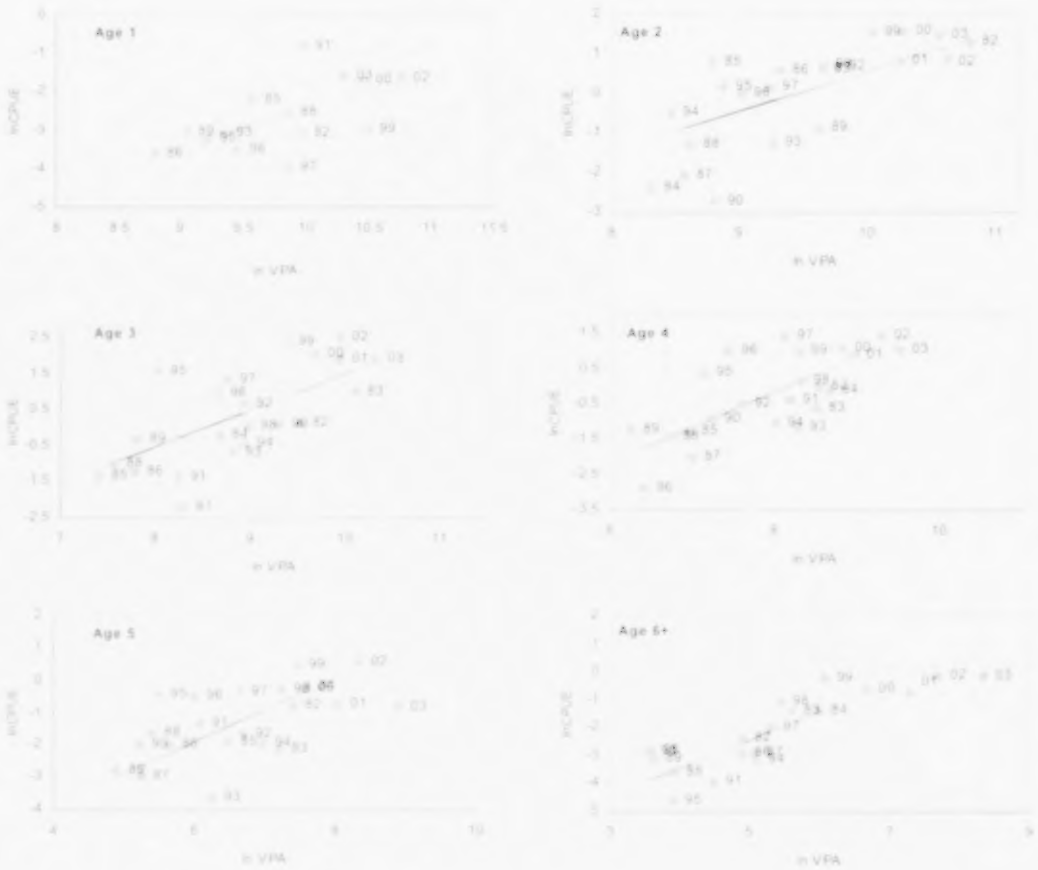


Figure 36. Age by age plots of the observed and predicted ln abundance index vs population numbers for Georges Bank yellowtail flounder from the NMFS spring survey Yankee 36 series, 1982-2004 from the Canadian ADAPT results.

Figure 37. Age by age plots of the observed and predicted ln abundance index vs population numbers for Georges Bank yellowtail flounder from the NMFS spring survey, Yankee 41 series, 1973-1981 from the Canadian ADAPT results.

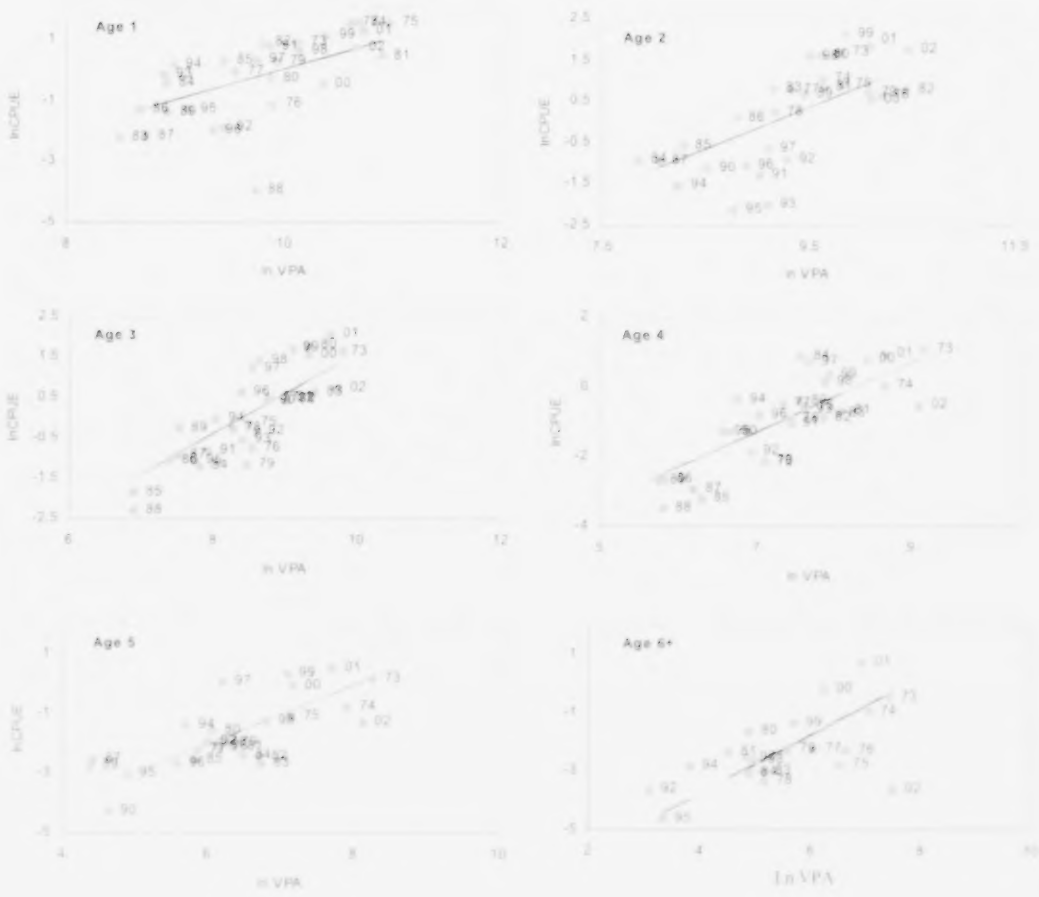


Figure 38. Age by age plots of the observed and predicted ln abundance index vs population numbers for Georges Bank yellowtail flounder from the NMFS fall survey, 1973-2003 from the Canadian ADAPT results.

Figure 39. Observed and predicted ln abundance index vs population numbers for Georges Bank age 1 yellowtail flounder from the NMFS scallop survey, 1982-2003 from the Canadian ADAPT results.

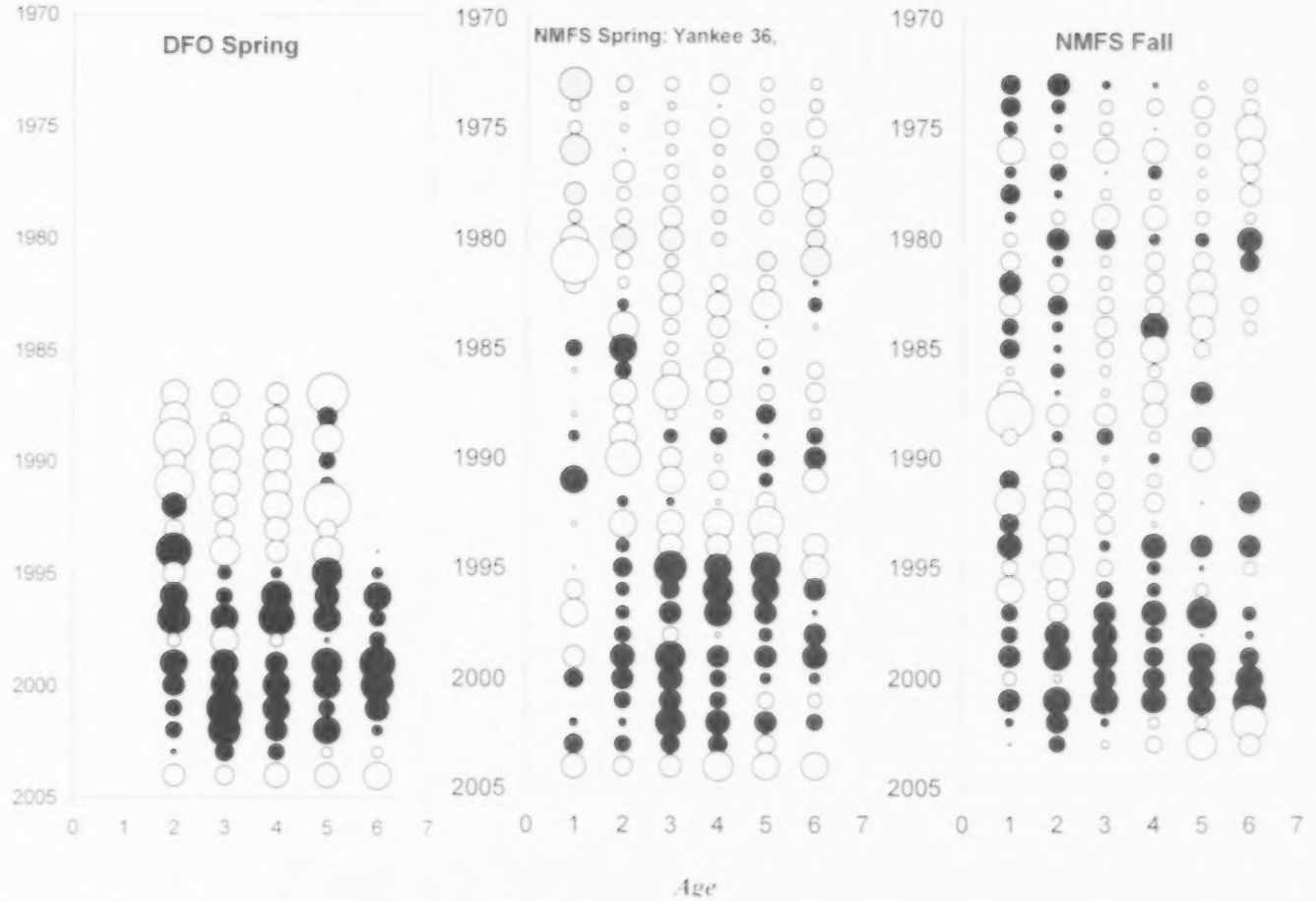


Figure 40. Age by age residuals for the relationships between ln abundance index versus ln population numbers, Georges Bank yellowtail flounder (bubble size is proportional to magnitude) from the Canadian ADAPT results. The grey shaded symbols in the NMFS spring series denote the period when the Yankee 41 net was used. The open symbols denote negative residuals, and closed symbols denote positive residuals.

Figure 41. Retrospective analysis of Georges Bank yellowtail flounder VPA for fishing mortality on ages 4-5 (top panel), spawning stock biomass (Middle panel) and age 1 recruits (lower panel) from the US FACT software.

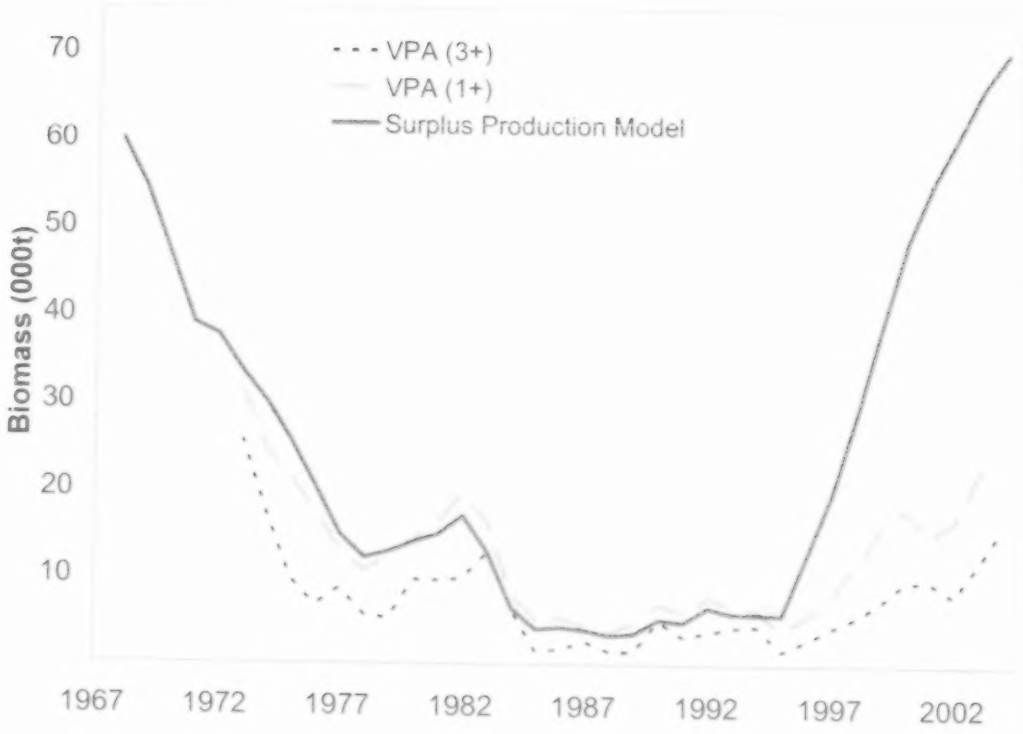


Figure 42. Trends in total (1+) and adult (3+) beginning of year biomass (000s t) as indicated from the Canadian ADAPT VPA and the surplus production model for yellowtail flounder on Georges Bank.

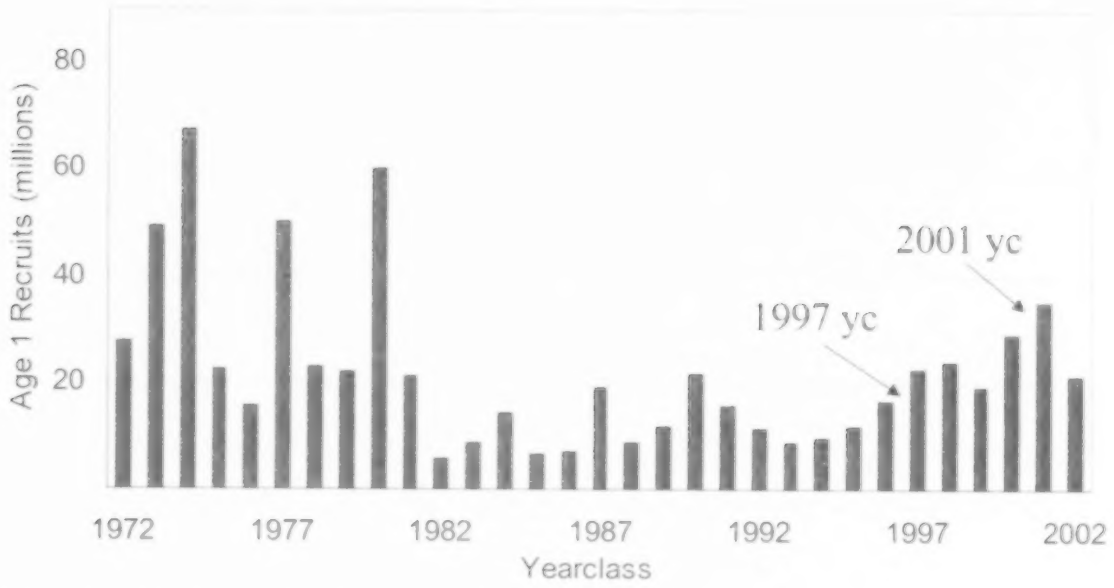


Figure 43. Age-1 recruitment estimates for Georges Bank yellowtail flounder, 1972-2002 from the Canadian ADAPT results. The 1997 and 2001 year classes are highlighted.

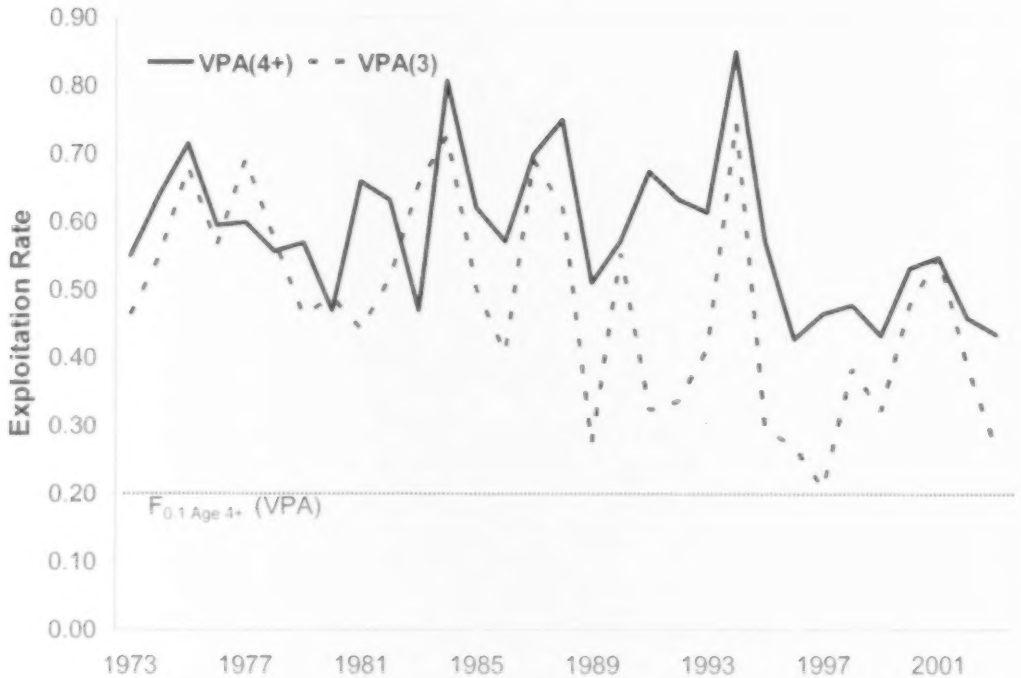


Figure 44. Trends in age 4+ (fully recruited) and age 3 exploitation rate from the Canadian ADAPT VPA for Georges Bank yellowtail flounder. Reference levels are shown for VPA age 4+.

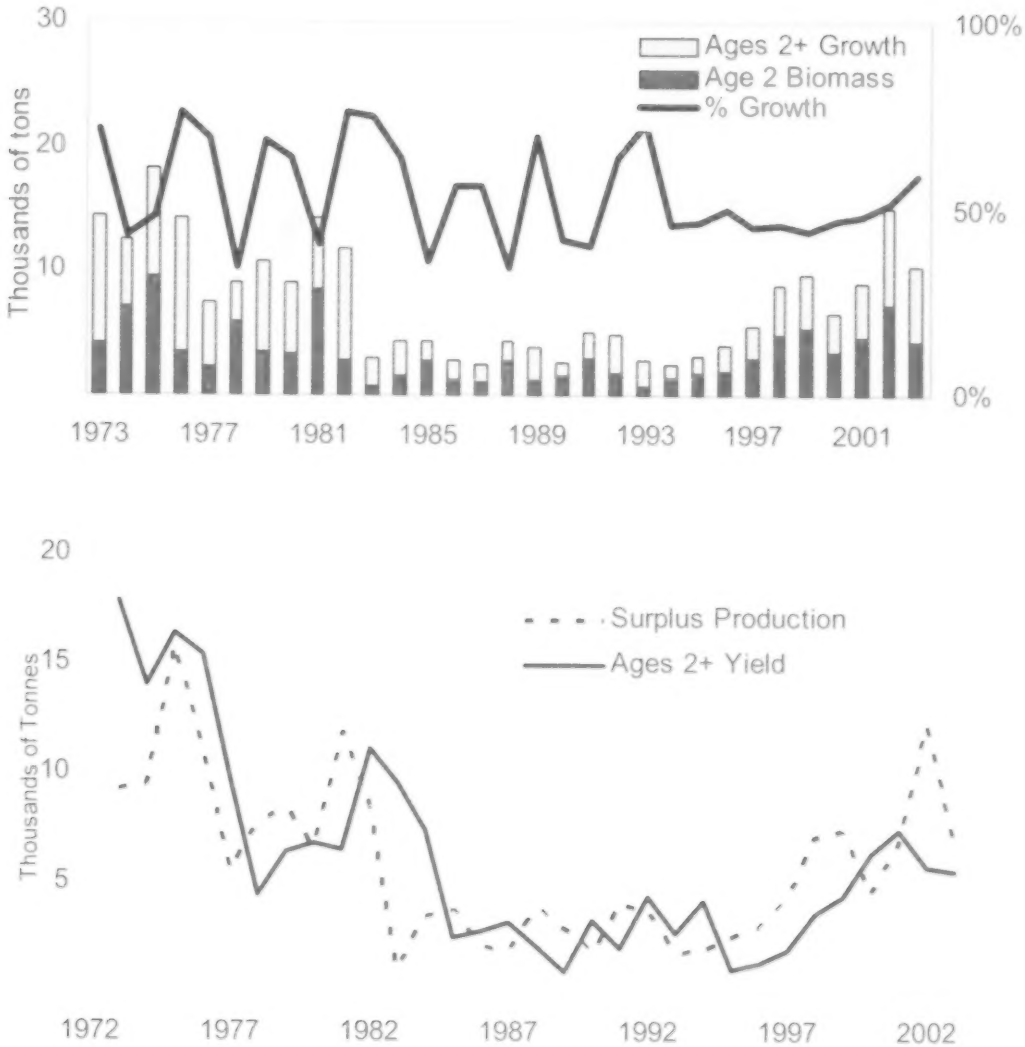


Figure 45. Components of production (top panel), and production as indicated by the Canadian ADAPT VPA, compared with fishery yield for Georges Bank yellowtail flounder.

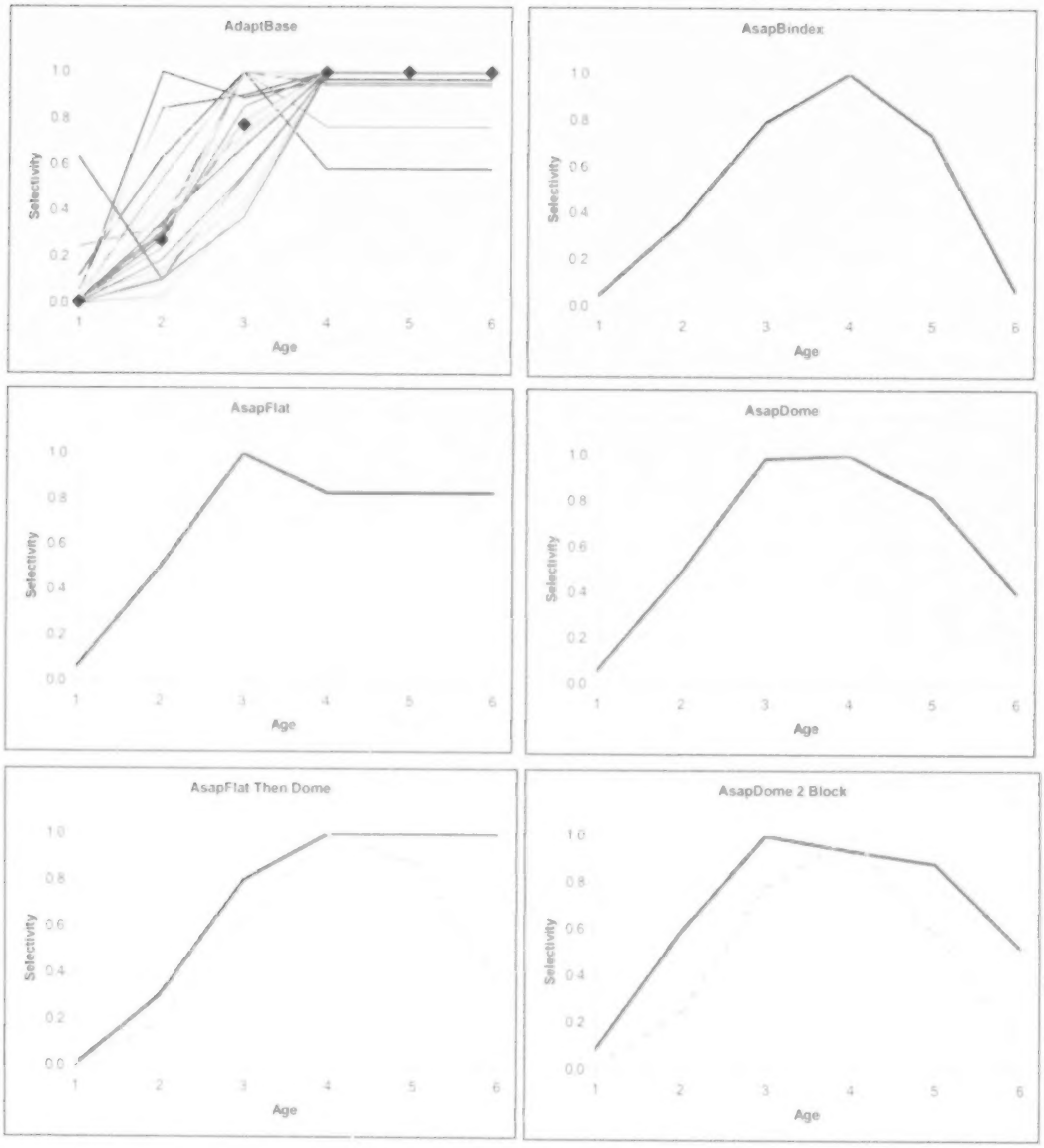


Figure 46. Selectivity at age for the US NFT VPA base case analysis (each line denotes a separate year and the diamonds denote the selectivity pattern used for projections) along with the different selelctivity patterns assumed or estimated in ASAP. For the ASAP selectivities, a single line means that pattern was applied to all years, if two lines are shown then the solid line is for years 1973-1993 and the dashed line for years 1994-2003.

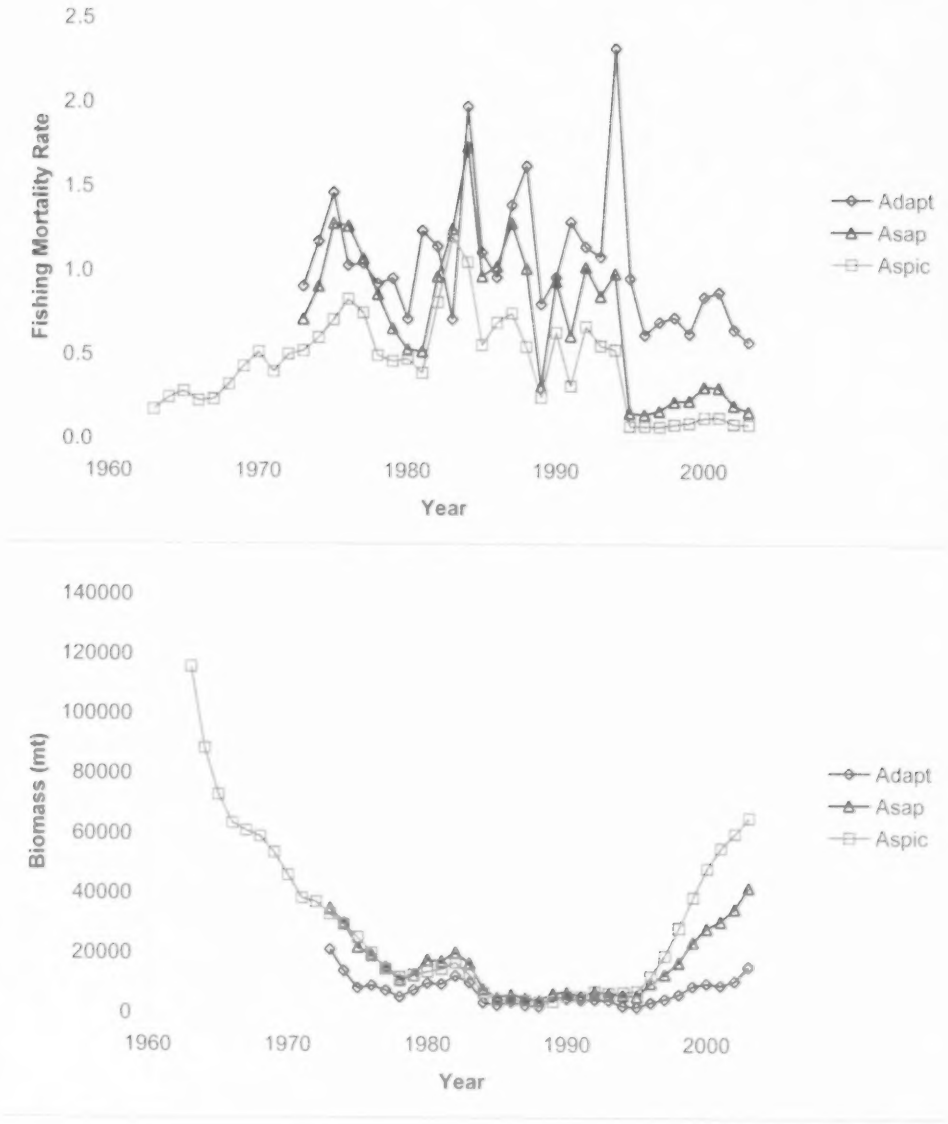


Figure 47. Comparison of US NFT VPA (Adapt), age structured assessment program (Asap), and surplus production model (Aspic). Note that the metrics for the three models differ so these are only approximate comparisons. The ASAP run shown assumes flat-topped selectivity for the entire time period.

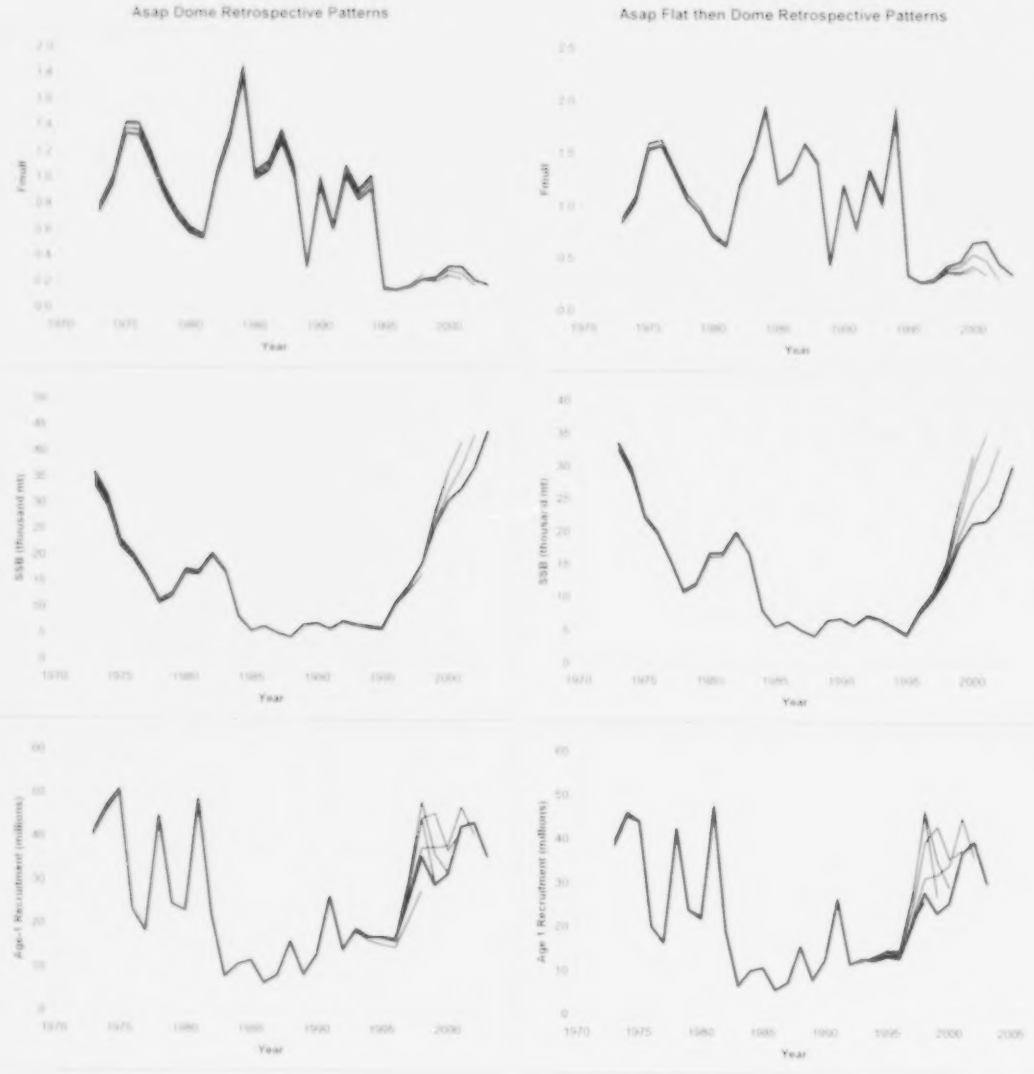


Figure 48. Retrospective patterns from two ASAP runs. Left panels allow the model to estimate a single selectivity pattern for the entire time series, which results in a dome shaped partial recruitment vector. Right panels fix the selectivity pattern to be flat-topped for years 1973-1993 and then allow the model to estimate a single selectivity pattern for the remaining years, which results in a dome shaped partial recruitment vector.

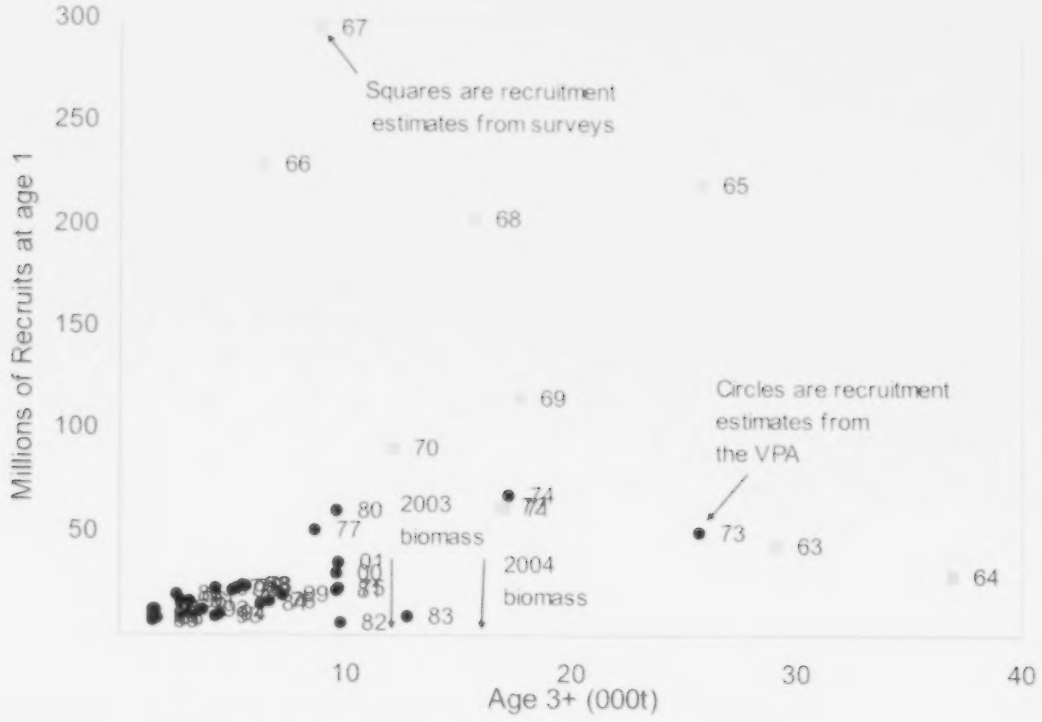


Figure 49. Age 3+ biomass and age 1 recruitment relationship from the Canadian ADAPT VPA for Georges Bank yellowtail flounder. The beginning of year age 3+ biomass for 2003 and 2004 from the VPA is also shown.

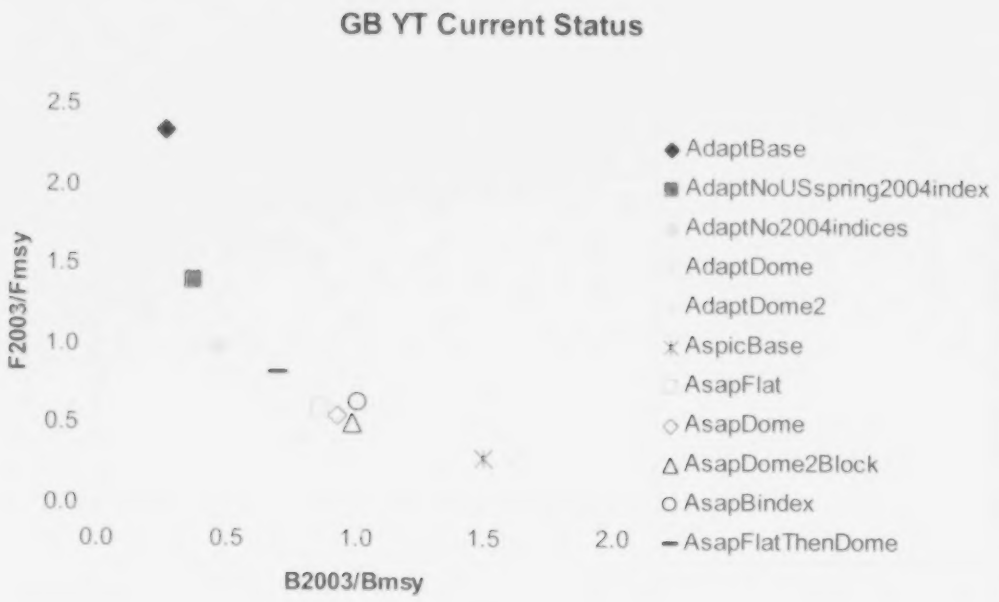


Figure 50. Current status estimated from a number of assessment models and formulations within models. The dashed lines show US reference points. See text for model run descriptions.

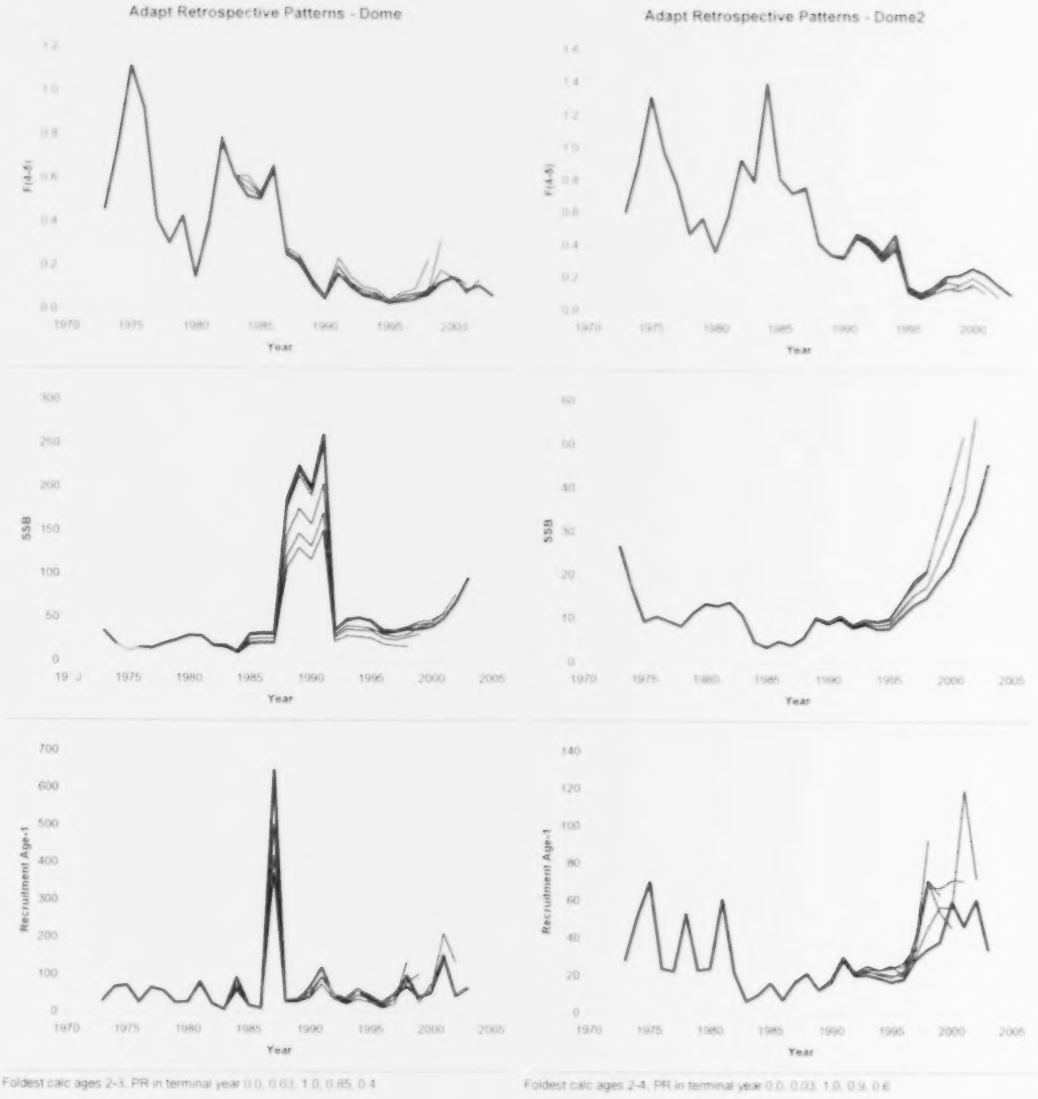

Adapt Retrospective Patterns - Dome
Adapt Retrospective Patterns - Dome2
F(4-5)
SSB
Recruitment Age-1
Year
Foldest calc ages 2-3, PR in terminal year 0.0, 0.63, 1.0, 0.85, 0.4
Foldest calc ages 2-4, PR in terminal year 0.0, 0.03, 1.0, 0.9, 0.6

Figure 51. Retrospective patterns from two domed sensitivity runs of the US NFT VPA. The left panels have a stronger dome assumed than the right panels.

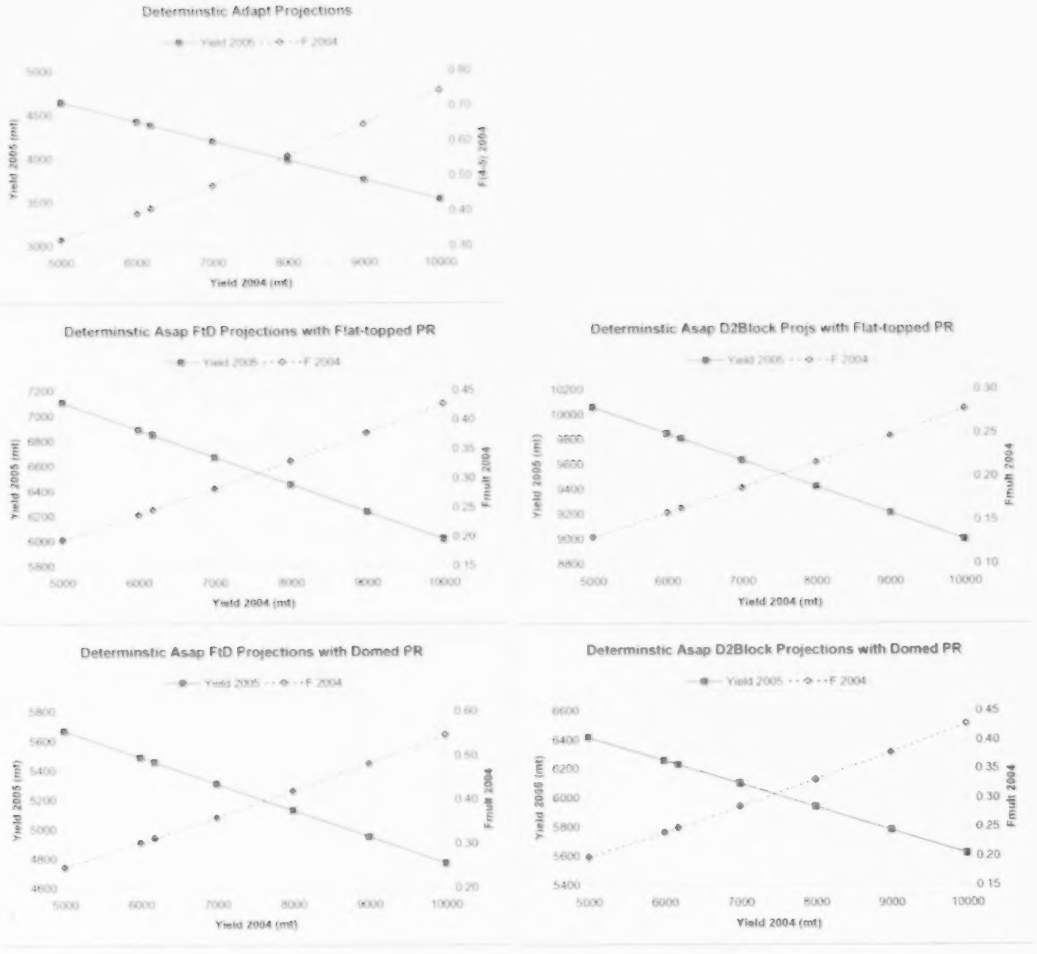


Figure 52. Yield in 2005 (t) and F in 2004 as a function of the yield taken in 2004 (t) for a range of models and assumptions regarding partial recruitment in the deterministic projections.

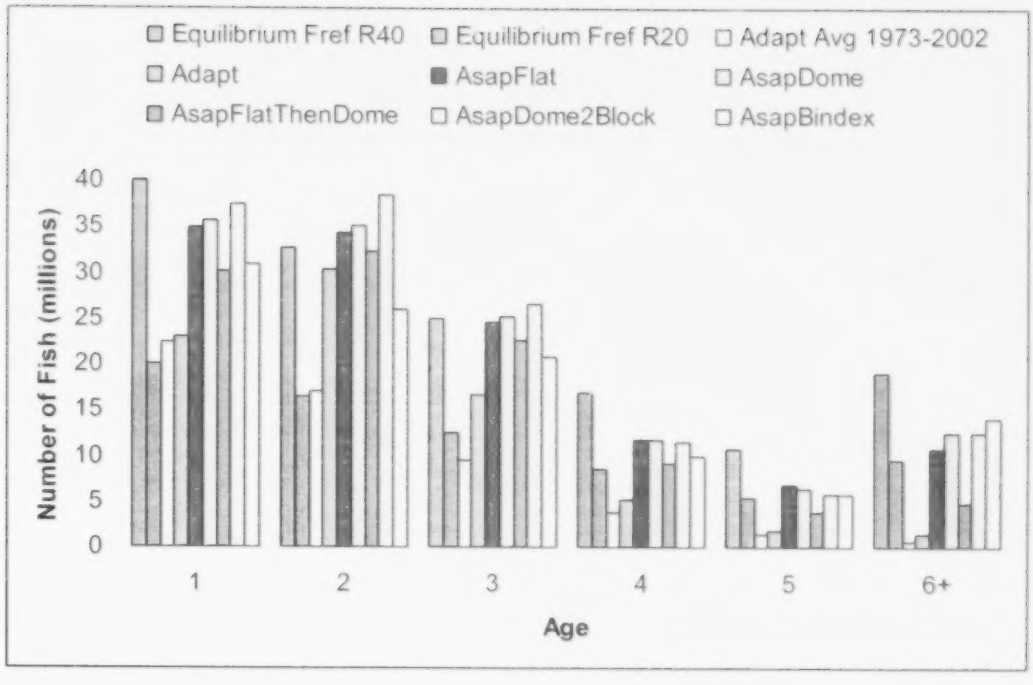


Figure 53. Number of fish at age (millions) for Georges Bank yellowtail flounder when the population is at equilibrium with recruitment of either 40 or 20 million age 1 fish and fished at Fref = 0.25 and the selectivity used in Adapt projections compared to a number of estimated population abundances in 2003 from US NFT VPA and ASAP model runs.

Appendix A
Surplus Production Analysis

Georges Bank Yellowtail (yield and biomass in k mt) Page 1
01 Jun 2004 at 13:19.11
ASPIC -- A Surplus-Production Model Including Covariates (Ver. 3.86) BOT Mode

Author: Michael H. Prager; NOAA/NMFS/S.E. Fisheries Science Center ASPIC User's Manual
101 Pivers Island Road; Beaufort, North Carolina 28516 USA is available gratis
from the author.

Ref: Prager, M. H. 1994. A suite of extensions to a nonequilibrium
surplus-production model. Fishery Bulletin 92: 374-389.

CONTROL PARAMETERS USED (FROM INPUT FILE)

Number of years analyzed:	41	Number of bootstrap trials:	500
Number of data series:	3	Lower bound on MSY:	5.000E+00
Objective function computed:	ln effort	Upper bound on MSY:	5.000E+01
Relative conv. criterion (simplex):	1.000E-09	Lower bound on r:	1.000E-01
Relative conv. criterion (restart):	3.000E-09	Upper bound on r:	5.000E+00
Relative conv. criterion (effort):	1.003E-05	Random number seed:	5844285
Maximum F allowed in fitting:	5.000	Monte Carlo search mode, trials:	2 50000

PROGRAM STATUS INFORMATION (NON-BOOTSTRAPPED ANALYSIS) code 5

Normal convergence.

CORRELATION AMONG INPUT SERIES EXPRESSED AS CPUE (NUMBER OF PAIRWISE OBSERVATIONS BELOW)

1 USA Fall	1.000		
	41		
2 USA Spring -lagged	0.816	1.000	
	28	28	
3 Canada - lagged	0.837	0.903	1.000
	18	18	18
	1	2	3

GOODNESS-OF-FIT AND WEIGHTING FOR NON-BOOTSTRAPPED ANALYSIS

Loss component number and title	Weighted SSE	N	Weighted MSE	Current weight	Suggested weight	R-squared in CPUE
Loss(-1) SSE in yield	0.000E+00					
Loss(0) Penalty for B1R > 2	0.000E+00	1	N/A	0.000E+00	N/A	
Loss(1) USA Fall	9.424E+00	41	2.417E-01	1.000E+00	1.059E+00	0.721
Loss(2) USA Spring -lagged	8.302E+00	26	3.193E-01	1.000E+00	8.013E-01	0.433
Loss(3) Canada - lagged	3.483E+00	18	2.177E-01	1.000E+00	1.175E+00	0.680
TOTAL OBJECTIVE FUNCTION:	2.12089156E+01					

Number of restarts required for convergence: 92
Est. B-ratio coverage index (0 worst, 2 best): 1.9143
Est. B-ratio nearness index (0 worst, 1 best): 1.0000

< These two measures are defined in Prager
< et al. (1996), Trans. A.F.S. 125:729

MODEL PARAMETER ESTIMATES (NON-BOOTSTRAPPED)

Parameter		Estimate	Starting guess	Estimated	User guess
B1R	Starting biomass ratio, year 1963	2.842E+00	1.000E+00	1	1
MSY	Maximum sustainable yield	1.408E+01	1.400E+01	1	1
r	Intrinsic rate of increase	6.420E-01	6.000E-01	1	1
.....	Catchability coefficients by fishery:				
q(1)	USA Fall	1.272E-01	1.000E-01	1	1
q(2)	USA Spring -lagged	1.348E-01	1.000E-01	1	1
q(3)	Canada - lagged	3.009E-01	3.000E-01	1	1

MANAGEMENT PARAMETER ESTIMATES (NON-BOOTSTRAPPED)

Parameter		Estimate	Formula	Related quantity
MSY	Maximum sustainable yield	1.408E+01	Rr/4	
K	Maximum stock biomass	8.772E+01		
Bmsy	Stock biomass at MSY	4.386E+01	K/2	
Fmsy	Fishing mortality at MSY	3.210E-01	r/2	
F(0.1)	Management benchmark	2.889E-01	0.9*Fmsy	
Y(0.1)	Equilibrium yield at F(0.1)	1.394E+01	0.99*MSY	
B-ratio	Ratio of B(2004) to Bmsy	1.603E+00		
F-ratio	Ratio of F(2003) to Fmsy	2.603E-01		
F01-mult	Ratio of F(0.1) to F(2003)	3.458E+00		
Y-ratio	Proportion of MSY avail in 2004	6.370E-01	2*Br-Br^2	Ye(2004) = 8.969E+00
.....	Fishing effort at MSY in units of each fishery:			
fmsy(1)	USA Fall	2.524E+00	r/2q(1)	f(0.1) = 2.271E+00

ESTIMATED POPULATION TRAJECTORY (NON-BOOTSTRAPPED)

Obs	Year or ID	Estimated total F mort	Estimated starting biomass	Estimated average biomass	Observed total yield	Model total yield	Estimated surplus production	Ratio of F mort to Fmsy	Ratio of biomass to Bmsy
1	1963	0.165	1.247E+02	1.058E+02	1.746E+01	1.746E+01	-1.461E+01	5.140E-01	2.842E+00
2	1964	0.238	9.260E+01	8.294E+01	1.977E+01	1.977E+01	2.730E+00	7.425E-01	2.111E+00
3	1965	0.276	7.556E+01	6.988E+01	1.931E+01	1.931E+01	9.063E+00	8.610E-01	1.723E+00
4	1966	0.223	6.531E+01	6.369E+01	1.419E+01	1.419E+01	1.120E+01	6.938E-01	1.489E+00
5	1967	0.232	6.232E+01	6.109E+01	1.420E+01	1.420E+01	1.191E+01	7.239E-01	1.421E+00
6	1968	0.321	6.003E+01	5.703E+01	1.832E+01	1.832E+01	1.279E+01	1.001E+00	1.369E+00
7	1969	0.426	5.451E+01	5.032E+01	2.145E+01	2.145E+01	1.374E+01	1.328E+00	1.243E+00
8	1970	0.512	4.680E+01	4.260E+01	2.179E+01	2.179E+01	1.403E+01	1.594E+00	1.067E+00
9	1971	0.397	3.904E+01	3.833E+01	1.521E+01	1.521E+01	1.386E+01	1.236E+00	8.900E-01
10	1972	0.500	3.769E+01	3.547E+01	1.773E+01	1.773E+01	1.355E+01	1.557E+00	8.592E-01
11	1973	0.522	3.351E+01	3.164E+01	1.652E+01	1.652E+01	1.298E+01	1.627E+00	7.640E-01
12	1974	0.601	2.997E+01	2.761E+01	1.659E+01	1.659E+01	1.213E+01	1.872E+00	6.832E-01
13	1975	0.704	2.551E+01	2.274E+01	1.601E+01	1.601E+01	1.080E+01	2.194E+00	5.817E-01
14	1976	0.826	2.030E+01	1.739E+01	1.436E+01	1.436E+01	8.934E+00	2.572E+00	4.628E-01
15	1977	0.744	1.488E+01	1.346E+01	1.001E+01	1.001E+01	7.312E+00	2.317E+00	3.392E-01
16	1978	0.494	1.218E+01	1.253E+01	6.188E+00	6.188E+00	6.898E+00	1.538E+00	2.776E-01
17	1979	0.461	1.289E+01	1.345E+01	6.195E+00	6.195E+00	7.309E+00	1.435E+00	2.938E-01
18	1980	0.475	1.400E+01	1.445E+01	6.863E+00	6.863E+00	7.747E+00	1.480E+00	3.192E-01
19	1981	0.394	1.489E+01	1.593E+01	6.277E+00	6.277E+00	8.367E+00	1.228E+00	3.394E-01
20	1982	0.811	1.698E+01	1.479E+01	1.200E+01	1.200E+01	7.883E+00	2.527E+00	3.870E-01
21	1983	1.200	1.286E+01	9.517E+00	1.142E+01	1.142E+01	5.426E+00	3.739E+00	2.932E-01
22	1984	1.047	6.865E+00	5.532E+00	5.791E+00	5.791E+00	3.324E+00	3.261E+00	1.565E-01
23	1985	0.559	4.398E+00	4.511E+00	2.520E+00	2.520E+00	2.747E+00	1.740E+00	1.003E-01
24	1986	0.688	4.625E+00	4.447E+00	3.060E+00	3.060E+00	2.711E+00	2.143E+00	1.055E-01
25	1987	0.742	4.276E+00	4.010E+00	2.975E+00	2.975E+00	2.457E+00	2.311E+00	9.749E-02
26	1988	0.544	3.758E+00	3.892E+00	2.118E+00	2.118E+00	2.388E+00	1.695E+00	8.567E-02
27	1989	0.249	4.027E+00	4.847E+00	1.207E+00	1.207E+00	2.938E+00	7.758E-01	9.182E-02
28	1990	0.629	5.758E+00	5.678E+00	3.569E+00	3.569E+00	3.409E+00	1.958E+00	1.313E-01
29	1991	0.314	5.599E+00	6.472E+00	2.030E+00	2.030E+00	3.847E+00	9.771E-01	1.276E-01
30	1992	0.662	7.415E+00	7.153E+00	4.732E+00	4.732E+00	4.218E+00	2.061E+00	1.691E-01
31	1993	0.546	6.901E+00	7.058E+00	3.853E+00	3.853E+00	4.167E+00	1.700E+00	1.573E-01
32	1994	0.518	7.215E+00	7.475E+00	3.869E+00	3.869E+00	4.390E+00	1.612E+00	1.645E-01
33	1995	0.079	7.736E+00	1.001E+01	7.880E-01	7.880E-01	5.680E+00	2.451E-01	1.764E-01
34	1996	0.080	1.263E+01	1.598E+01	1.273E+00	1.273E+00	8.360E+00	2.482E-01	2.879E-01
35	1997	0.076	1.972E+01	2.424E+01	1.834E+00	1.834E+00	1.121E+01	2.357E-01	4.495E-01
36	1998	0.090	2.909E+01	3.417E+01	3.087E+00	3.087E+00	1.333E+01	2.815E-01	6.632E-01
37	1999	0.100	3.933E+01	4.421E+01	4.441E+00	4.441E+00	1.402E+01	3.129E-01	8.967E-01
38	2000	0.132	4.891E+01	5.237E+01	6.895E+00	6.895E+00	1.352E+01	4.101E-01	1.115E+00
39	2001	0.124	5.554E+01	5.835E+01	7.211E+00	7.211E+00	1.253E+01	3.850E-01	1.266E+00
40	2002	0.088	6.086E+01	6.379E+01	5.640E+00	5.640E+00	1.116E+01	2.754E-01	1.387E+00
41	2003	0.084	6.637E+01	6.848E+01	5.721E+00	5.721E+00	9.637E+00	2.603E-01	1.513E+00
42	2004		7.029E+01						1.603E+00

RESULTS FOR DATA SERIES # 1 (NON-BOOTSTRAPPED) USA Fall

Data type CC: CPUE-catch series Series weight: 1.000

Obs	Year	Observed CPUE	Estimated CPUE	Estim F	Observed yield	Model yield	Resid in log scale	Resid in log yield
1	1963	1.279E+01	1.346E+01	0.1650	1.746E+01	1.746E+01	0.05185	0.000E+00
2	1964	1.362E+01	1.055E+01	0.2383	1.977E+01	1.977E+01	-0.25567	0.000E+00
3	1965	9.204E+00	8.888E+00	0.2764	1.531E+01	1.531E+01	-0.02498	0.000E+00
4	1966	8.988E+00	8.101E+00	0.2327	1.419E+01	1.419E+01	0.10872	0.000E+00
5	1967	7.575E+00	7.770E+00	0.2324	1.420E+01	1.420E+01	0.02541	0.000E+00
6	1968	1.054E+01	7.254E+00	0.3212	1.832E+01	1.832E+01	-0.37320	0.000E+00
7	1969	9.279E+00	6.400E+00	0.4263	2.145E+01	2.145E+01	-0.37145	0.000E+00
8	1970	4.979E+00	5.418E+00	0.5116	2.179E+01	2.179E+01	0.08453	0.000E+00
9	1971	6.365E+00	4.875E+00	0.3967	1.521E+01	1.521E+01	-0.26675	0.000E+00
10	1972	6.326E+00	4.511E+00	0.4999	1.773E+01	1.773E+01	-0.33843	0.000E+00
11	1973	6.602E+00	4.024E+00	0.5223	1.652E+01	1.652E+01	-0.49509	0.000E+00
12	1974	3.733E+00	3.511E+00	0.6009	1.659E+01	1.659E+01	-0.06125	0.000E+00
13	1975	2.365E+00	2.892E+00	0.7042	1.601E+01	1.601E+01	0.20108	0.000E+00
14	1976	1.533E+00	2.212E+00	0.8255	1.436E+01	1.436E+01	0.36668	0.000E+00
15	1977	2.929E+00	1.712E+00	0.7437	1.001E+01	1.001E+01	-0.50221	0.000E+00
16	1978	2.381E+00	1.594E+00	0.4937	6.188E+00	6.188E+00	-0.40190	0.000E+00
17	1979	1.520E+00	1.710E+00	0.4607	6.195E+00	6.195E+00	0.11790	0.000E+00
18	1980	6.722E+00	1.838E+00	0.4751	6.863E+00	6.863E+00	-1.29697	0.000E+00
19	1981	2.621E+00	2.026E+00	0.3941	6.277E+00	6.277E+00	-0.25754	0.000E+00
20	1982	2.270E+00	1.881E+00	0.8124	1.200E+01	1.200E+01	-0.18813	0.000E+00
21	1983	2.131E+00	1.210E+00	1.2002	1.142E+01	1.142E+01	-0.56557	0.000E+00
22	1984	5.930E-01	7.036E-01	1.0468	5.791E+00	5.791E+00	0.17104	0.000E+00
23	1985	7.060E-01	5.738E-01	0.5586	2.520E+00	2.520E+00	-0.21155	0.000E+00
24	1986	8.200E-01	5.657E-01	0.6880	3.060E+00	3.060E+00	-0.37126	0.000E+00
25	1987	5.090E-01	5.100E-01	0.7419	2.975E+00	2.975E+00	0.00206	0.000E+00
26	1988	1.710E-01	4.950E-01	0.5442	2.118E+00	2.118E+00	1.06289	0.000E+00
27	1989	9.770E-01	6.165E-01	0.2490	1.207E+00	1.207E+00	-0.46050	0.000E+00
28	1990	7.250E-01	7.222E-01	0.6286	3.569E+00	3.569E+00	-0.00392	0.000E+00
29	1991	7.300E-01	8.232E-01	0.3137	2.030E+00	2.030E+00	0.12010	0.000E+00
30	1992	5.760E-01	9.048E-01	0.6616	4.732E+00	4.732E+00	0.45711	0.000E+00
31	1993	5.450E-01	8.978E-01	0.5455	3.853E+00	3.853E+00	0.49912	0.000E+00
32	1994	8.970E-01	8.508E-01	0.5176	3.869E+00	3.869E+00	0.05821	0.000E+00
33	1995	3.540E-01	1.274E+00	0.0787	7.880E-01	7.880E-01	1.28031	0.000E+00
34	1996	1.303E+00	2.032E+00	0.0797	1.273E+00	1.273E+00	0.44453	0.000E+00
35	1997	3.781E+00	3.083E+00	0.0757	1.834E+00	1.834E+00	-0.20414	0.000E+00
36	1998	4.347E+00	4.346E+00	0.0904	3.087E+00	3.087E+00	-0.00031	0.000E+00
37	1999	7.973E+00	5.623E+00	0.1005	4.441E+00	4.441E+00	-0.34926	0.000E+00
38	2000	5.838E+00	6.661E+00	0.1317	6.895E+00	6.895E+00	0.13187	0.000E+00
39	2001	1.155E+01	7.422E+00	0.1236	7.211E+00	7.211E+00	-0.44256	0.000E+00
40	2002	3.754E+00	8.114E+00	0.0884	5.640E+00	5.640E+00	0.77073	0.000E+00
41	2003	4.039E+00	8.710E+00	0.0835	5.721E+00	5.721E+00	0.76844	0.000E+00

UNWEIGHTED LOG RESIDUAL PLOT FOR DATA SERIES # 1

RESULTS FOR DATA SERIES # 2 (NON-BOOTSTRAPPED) USA Spring -lagged

Data type I2: End-of-year biomass index Series weight: 1.000

Obs	Year	Observed effort	Estimated effort	Estim F	Observed index	Model index	Resid in log index	Resid in index
1	1963	0.000E+00	0.000E+00	0.0	*	1.248E+01	0.00000	0.0
2	1964	0.000E+00	0.000E+00	0.0	*	1.019E+01	0.00000	0.0
3	1965	0.000E+00	0.000E+00	0.0	*	8.804E+00	0.00000	0.0
4	1966	0.000E+00	0.000E+00	0.0	*	8.402E+00	0.00000	0.0
5	1967	1.000E+00	1.000E+00	0.0	2.813E+00	8.093E+00	-1.05673	-5.280E+00
6	1968	1.000E+00	1.000E+00	0.0	1.117E+01	7.348E+00	0.41886	3.822E+00
7	1969	1.000E+00	1.000E+00	0.0	5.312E+00	6.308E+00	-0.17190	-9.963E-01
8	1970	1.000E+00	1.000E+00	0.0	4.607E+00	5.262E+00	-0.13297	-6.552E-01
9	1971	1.000E+00	1.000E+00	0.0	6.450E+00	5.080E+00	0.23878	1.370E+00
10	1972	0.000E+00	0.000E+00	0.0	*	4.517E+00	0.00000	0.0
11	1973	0.000E+00	0.000E+00	0.0	*	4.040E+00	0.00000	0.0
12	1974	0.000E+00	0.000E+00	0.0	*	3.439E+00	0.00000	0.0
13	1975	0.000E+00	0.000E+00	0.0	*	2.737E+00	0.00000	0.0
14	1976	0.000E+00	0.000E+00	0.0	*	2.006E+00	0.00000	0.0
15	1977	0.000E+00	0.000E+00	0.0	*	1.642E+00	0.00000	0.0
16	1978	0.000E+00	0.000E+00	0.0	*	1.737E+00	0.00000	0.0
17	1979	0.000E+00	0.000E+00	0.0	*	1.887E+00	0.00000	0.0
18	1980	0.000E+00	0.000E+00	0.0	*	2.007E+00	0.00000	0.0
19	1981	1.000E+00	1.000E+00	0.0	2.500E+00	2.288E+00	0.08847	2.117E-01
20	1982	1.000E+00	1.000E+00	0.0	2.842E+00	1.744E+00	0.42125	4.083E-01
21	1983	1.000E+00	1.000E+00	0.0	1.646E+00	9.254E-01	0.57586	7.206E-01
22	1984	1.000E+00	1.000E+00	0.0	9.880E-01	5.929E-01	0.51073	3.951E-01
23	1985	1.000E+00	1.000E+00	0.0	8.470E-01	6.235E-01	0.30632	2.235E-01
24	1986	1.000E+00	1.000E+00	0.0	3.290E-01	5.764E-01	-0.56078	-2.474E-01
25	1987	1.000E+00	1.000E+00	0.0	5.660E-01	5.066E-01	0.11095	5.944E-02
26	1988	1.000E+00	1.000E+00	0.0	7.290E-01	5.429E-01	0.29471	1.861E-01
27	1989	1.000E+00	1.000E+00	0.0	6.990E-01	7.763E-01	-0.10483	-7.726E-02
28	1990	1.000E+00	1.000E+00	0.0	6.310E-01	7.547E-01	-0.17906	-1.237E-01
29	1991	1.000E+00	1.000E+00	0.0	1.566E+00	9.996E-01	0.44892	5.664E-01
30	1992	1.000E+00	1.000E+00	0.0	4.820E-01	9.303E-01	-0.65755	-4.483E-01
31	1993	1.000E+00	1.000E+00	0.0	6.600E-01	9.726E-01	-0.38775	-3.126E-01
32	1994	1.000E+00	1.000E+00	0.0	2.579E+00	1.043E+00	0.90543	1.536E+00
33	1995	1.000E+00	1.000E+00	0.0	2.853E+00	1.702E+00	0.51635	1.151E+00
34	1996	1.000E+00	1.000E+00	0.0	4.359E+00	2.658E+00	0.49479	1.701E+00
35	1997	1.000E+00	1.000E+00	0.0	2.324E+00	3.921E+00	-0.52314	-1.597E+00
36	1998	1.000E+00	1.000E+00	0.0	9.307E+00	5.302E+00	0.56271	4.005E+00
37	1999	1.000E+00	1.000E+00	0.0	6.696E+00	6.594E+00	0.01541	1.024E-01
38	2000	1.000E+00	1.000E+00	0.0	5.008E+00	7.487E+00	-0.40216	-2.479E+00
39	2001	1.000E+00	1.000E+00	0.0	9.563E+00	8.204E+00	0.15329	1.359E+00
40	2002	1.000E+00	1.000E+00	0.0	6.721E+00	8.947E+00	-0.28613	-2.226E+00
41	2003	1.000E+00	1.000E+00	0.0	1.887E+00	9.475E+00	-1.61370	-7.588E+00

* Asterisk indicates missing value(s).

UNWEIGHTED LOG RESIDUAL PLOT FOR DATA SERIES # 2

Year	Residual	-2 -1.5 -1 -0.5 0 0.5 1 1.5 2
1963	0.0000	
1964	0.0000	
1965	0.0000	
1966	0.0000	
1967	-1.0567	========== |
1968	0.4189	| ========
1969	-0.1719	=== |
1970	-0.1330	=== |
1971	0.2387	| =====
1972	0.0000	
1973	0.0000	
1974	0.0000	
1975	0.0000	
1976	0.0000	
1977	0.0000	
1978	0.0000	
1979	0.0000	
1980	0.0000	
1981	0.0885	| ==
1982	0.4213	| ========
1983	0.5759	| ============
1984	0.5107	| ==========
1985	0.3063	| ======
1986	-0.5608	========== |
1987	0.1110	| ==
1988	0.2947	| ======
1989	-0.1048	== |
1990	-0.1791	==== |
1991	0.4489	| =========
1992	-0.6576	============ |
1993	-0.3878	======== |
1994	0.9054	| ==================
1995	0.5163	| ==========
1996	0.4948	| ==========
1997	-0.5231	========== |
1998	0.5627	| ==========
1999	0.0154	
2000	-0.4022	======== |
2001	0.1533	| ===
2002	-0.2861	====== |
2003	-1.6137	================================ |

RESULTS FOR DATA SERIES # 3 (NON-BOOTSTRAPPED) Canada - lagged

Data type I2: End-of-year biomass index Series weight: 1.000

Obs	Year	Observed effort	Estimated effort	Estim F	Observed index	Model index	Resid in log index	Resid in index
1	1963	0.000E+00	0.000E+00	0.0	*	2.787E+01	0.00000	0.0
2	1964	0.000E+00	0.000E+00	0.0	*	2.274E+01	0.00000	0.0
3	1965	0.000E+00	0.000E+00	0.0	*	1.965E+01	0.00000	0.0
4	1966	0.000E+00	0.000E+00	0.0	*	1.875E+01	0.00000	0.0
5	1967	0.000E+00	0.000E+00	0.0	*	1.806E+01	0.00000	0.0
6	1968	0.000E+00	0.000E+00	0.0	*	1.640E+01	0.00000	0.0
7	1969	0.000E+00	0.000E+00	0.0	*	1.408E+01	0.00000	0.0
8	1970	0.000E+00	0.000E+00	0.0	*	1.175E+01	0.00000	0.0
9	1971	0.000E+00	0.000E+00	0.0	*	1.134E+01	0.00000	0.0
10	1972	0.000E+00	0.000E+00	0.0	*	1.008E+01	0.00000	0.0
11	1973	0.000E+00	0.000E+00	0.0	*	9.017E+00	0.00000	0.0
12	1974	0.000E+00	0.000E+00	0.0	*	7.677E+00	0.00000	0.0
13	1975	0.000E+00	0.000E+00	0.0	*	6.108E+00	0.00000	0.0
14	1976	0.000E+00	0.000E+00	0.0	*	4.477E+00	0.00000	0.0
15	1977	0.000E+00	0.000E+00	0.0	*	3.664E+00	0.00000	0.0
16	1978	0.000E+00	0.000E+00	0.0	*	3.878E+00	0.00000	0.0
17	1979	0.000E+00	0.000E+00	0.0	*	4.213E+00	0.00000	0.0
18	1980	0.000E+00	0.000E+00	0.0	*	4.479E+00	0.00000	0.0
19	1981	0.000E+00	0.000E+00	0.0	*	5.108E+00	0.00000	0.0
20	1982	0.000E+00	0.000E+00	0.0	*	3.870E+00	0.00000	0.0
21	1983	0.000E+00	0.000E+00	0.0	*	2.066E+00	0.00000	0.0
22	1984	0.000E+00	0.000E+00	0.0	*	1.323E+00	0.00000	0.0
23	1985	0.000E+00	0.000E+00	0.0	*	1.392E+00	0.00000	0.0
24	1986	1.000E+00	1.000E+00	0.0	1.264E+00	1.287E+00	-0.01780	-2.269E-02
25	1987	1.000E+00	1.000E+00	0.0	1.235E+00	1.131E+00	0.08819	1.043E-01
26	1988	1.000E+00	1.000E+00	0.0	4.710E-01	1.212E+00	-0.94509	-7.409E-01
27	1989	1.000E+00	1.000E+00	0.0	1.578E+00	1.733E+00	-0.09356	-1.548E-01
28	1990	1.000E+00	1.000E+00	0.0	1.759E+00	1.685E+00	0.04314	7.428E-02
29	1991	1.000E+00	1.000E+00	0.0	2.475E+00	2.231E+00	0.10364	2.437E-01
30	1992	1.000E+00	1.000E+00	0.0	2.642E+00	2.077E+00	0.24080	5.654E-01
31	1993	1.000E+00	1.000E+00	0.0	2.753E+00	2.171E+00	0.23746	5.819E-01
32	1994	1.000E+00	1.000E+00	0.0	2.027E+00	2.328E+00	-0.13840	-3.009E-01
33	1995	1.000E+00	1.000E+00	0.0	5.304E+00	3.800E+00	0.33344	1.504E+00
34	1996	1.000E+00	1.000E+00	0.0	1.329E+01	5.932E+00	0.80672	7.360E+00
35	1997	1.000E+00	1.000E+00	0.0	4.292E+00	8.753E+00	-0.71267	-4.461E+00
36	1998	1.000E+00	1.000E+00	0.0	1.767E+01	1.183E+01	0.40059	5.831E+00
37	1999	1.000E+00	1.000E+00	0.0	1.995E+01	1.472E+01	0.30414	5.232E+00
38	2000	1.000E+00	1.000E+00	0.0	2.216E+01	1.671E+01	0.28196	5.444E+00
39	2001	1.000E+00	1.000E+00	0.0	2.062E+01	1.831E+01	0.11885	2.311E+00
40	2002	1.000E+00	1.000E+00	0.0	1.625E+01	1.997E+01	-0.20633	-3.724E+00
41	2003	1.000E+00	1.000E+00	0.0	8.909E+00	2.115E+01	-0.87602	-1.234E+01

* Asterisk indicates missing value(s).

UNWEIGHTED LOG RESIDUAL PLOT FOR DATA SERIES # 3

Year	Residual
1963	0.0000
1964	0.0000
1965	0.0000
1966	0.0000
1967	0.0000
1968	0.0000
1969	0.0000
1970	0.0000
1971	0.0000
1972	0.0000
1973	0.0000
1974	0.0000
1975	0.0000
1976	0.0000
1977	0.0000
1978	0.0000
1979	0.0000
1980	0.0000
1981	0.0000
1982	0.0000
1983	0.0000
1984	0.0000
1985	0.0000
1986	-0.0178
1987	0.0882
1988	-0.9451
1989	-0.0936
1990	0.0431
1991	0.1036
1992	0.2408
1993	0.2375
1994	-0.1384
1995	0.3334
1996	0.8067
1997	-0.7127
1998	0.4006
1999	0.3041
2000	0.2820
2001	0.1189
2002	-0.2063
2003	-0.8760

RESULTS OF BOOTSTRAPPED ANALYSIS

Param name	Bias-corrected estimate	Ordinary estimate	Relative bias	Approx 80% lower CL	Approx 80% upper CL	Approx 50% lower CL	Approx 50% upper CL	Inter-quartile range	Relative IQ range
Blratio	2.833E+00	2.842E+00	0.35%	2.372E+00	3.064E+00	2.704E+00	2.914E+00	2.101E-01	0.074
K	8.825E+01	8.772E+01	-0.60%	8.439E+01	9.781E+01	8.673E+01	9.094E+01	4.212E+00	0.048
r	6.370E-01	6.420E-01	0.78%	5.713E-01	6.779E-01	6.112E-01	6.536E-01	4.243E-02	0.067
q(1)	1.272E-01	1.272E-01	0.03%	1.133E-01	1.369E-01	1.219E-01	1.312E-01	9.263E-03	0.073
q(2)	1.354E-01	1.348E-01	-0.47%	1.184E-01	1.536E-01	1.273E-01	1.435E-01	1.622E-02	0.120
q(3)	3.016E-01	3.009E-01	-0.23%	2.501E-01	3.594E-01	2.782E-01	3.313E-01	5.306E-02	0.176
MSY	1.404E+01	1.408E+01	0.29%	1.357E+01	1.432E+01	1.390E+01	1.416E+01	2.670E-01	0.019
Ye(2004)	9.210E+00	8.969E+00	-2.62%	8.177E+00	1.053E+01	8.656E+00	9.865E+00	1.208E+00	0.131
Bmsy	4.413E+01	4.386E+01	-0.60%	4.220E+01	4.890E+01	4.336E+01	4.547E+01	2.106E+00	0.048
Fmsy	3.185E-01	3.210E-01	0.78%	2.857E-01	3.389E-01	3.056E-01	3.268E-01	2.122E-02	0.067
fmsy(1)	2.497E+00	2.524E+00	1.09%	2.291E+00	2.704E+00	2.384E+00	2.584E+00	2.002E-01	0.080
fmsy(2)	2.348E+00	2.381E+00	1.40%	2.104E+00	2.620E+00	2.205E+00	2.484E+00	2.785E-01	0.119
fmsy(3)	1.059E+00	1.067E+00	0.72%	9.001E-01	1.273E+00	9.777E-01	1.160E+00	1.824E-01	0.172
F(0.1)	2.867E-01	2.889E-01	0.70%	2.571E-01	3.050E-01	2.750E-01	2.941E-01	1.910E-02	0.067
Y(0.1)	1.390E+01	1.394E+01	0.29%	1.343E+01	1.418E+01	1.376E+01	1.402E+01	2.643E-01	0.019
B-ratio	1.588E+00	1.603E+00	0.94%	1.497E+00	1.652E+00	1.539E+00	1.624E+00	8.508E-02	0.054
F-ratio	2.635E-01	2.603E-01	-1.24%	2.486E-01	2.890E-01	2.559E-01	2.774E-01	2.144E-02	0.081
Y-ratio	6.553E-01	6.370E-01	-2.79%	5.745E-01	7.526E-01	6.112E-01	7.099E-01	9.871E-02	0.151
f0.1(1)	2.247E+00	2.271E+00	0.98%	2.062E+00	2.433E+00	2.145E+00	2.326E+00	1.802E-01	0.080
f0.1(2)	2.114E+00	2.143E+00	1.26%	1.894E+00	2.358E+00	1.985E+00	2.235E+00	2.506E-01	0.119
f0.1(3)	9.533E-01	9.601E-01	0.65%	8.101E-01	1.146E+00	8.799E-01	1.044E+00	1.642E-01	0.172
q2/q1	1.057E+00	1.060E+00	0.23%	9.069E-01	1.214E+00	9.685E-01	1.120E+00	1.515E-01	0.143
q3/q1	2.364E+00	2.366E+00	0.08%	1.975E+00	2.834E+00	2.160E+00	2.573E+00	4.135E-01	0.175

NOTES ON BOOTSTRAPPED ESTIMATES

- The bootstrapped results shown were computed from 500 trials.
- These results are conditional on the constraints placed upon MSY and r in the input file (ASPIC.INP).
- All bootstrapped intervals are approximate. The statistical literature recommends using at least 1000 trials for accurate 95% intervals. The 80% intervals used by ASPIC should require fewer trials for equivalent accuracy. Using at least 500 trials is recommended.
- The bias corrections used here are based on medians. This is an accepted statistical procedure, but may estimate nonzero bias for unbiased, skewed estimators.

Trials replaced for lack of convergence: 108
Trials replaced for MSY out-of-bounds: 0
Trials replaced for r out-of-bounds: 0
Residual-adjustment factor: 1.0364